

SPECIAL  
REPORT

**THE NEXT CYBERATTACK**  
COULD COME FROM YOUR COFFEEMAKER

**PLUS!** INSIDE AMAZON'S  
DRONE LAB PG.19

# POPULAR SCIENCE

**STRESS**

**IT'S  
KILLING  
YOU**

How to  
Beat It with  
Science

→  
It doesn't have  
to be this way!

**DIY  
HOVERCRAFT**

TAKE OFF  
IN AN HOUR

**WHY IS  
EVERYONE  
SO SCARED OF  
ARTIFICIAL  
INTELLIGENCE?**

RELAX, STEPHEN HAWKING



MARCH 2015

**INTRODUCING  
THE VIZZIES**

PG.52

**15**  
MUST-HAVE  
GADGETS

**RISE OF  
THE DWARF  
PLANETS**

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**SANDWICHES—  
FRIEND OR FOE?**  
RETHINKING AMERICA'S  
FAVORITE LUNCH





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# 38

## THE SCIENCE OF STRESS

Snowed under? Us too. Here's how stress works—and how to beat it.

**BROOKE BOREL**

## Featuring

### CULTURED COUTURE

Forget cows. Designer Suzanne Lee is growing leather in a lab.

**DANIEL GRUSHKIN**

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### THE VIZZIES

*Popular Science* and the National Science Foundation honor the year's best science and engineering visualizations.

**KATIE PEEK**

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### NOWHERE TO HIDE

Hardware governs our homes, cities, infrastructure, and military. What happens when it's turned against us?

**P.W. SINGER**

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For geeky DIY projects, vintage covers, and visual nerdery find us at [pinterest.com/popularscience](http://pinterest.com/popularscience)



### ON THE COVER

Studies have shown that play eases stress—in humans, not toys. Photograph by **Sam Kaplan**

## From the Editor

# Death, Taxes, and Deadlines

**A** few months ago, I caught up with a buddy for a drink. He's in advertising, and like most of his colleagues, he works awful hours. Nights, weekends, you name it. But it didn't appear to bother him. He always seemed like one of those corporate ironmen, the guys suspiciously impervious to heavy workloads

and overly demanding bosses.

But on that night, my buddy came clean. He told me he stopped sleeping well a few years before. Then he'd gotten a weird back pain that wouldn't go away, so he slept even less. At the same time, his job ramped up. In pain and perpetually tired, he was working even more. Eventually, this all became intolerable, so one morning he marched over to his boss, gave his two weeks notice, and resolved to figure out some other source of income.

When I asked him why he hadn't held out until he'd found that next best thing, he said, "I just couldn't live one more day with that stress."

In magazines, we often joke that in this world nothing is certain but death, taxes, and deadlines. For us editors, stress is a fact of life, sometimes even a badge of honor, but I'd be lying if I said it doesn't get to me sometimes. In this, I am not alone. Workplace stress in the U.S. has been rising consistently. Even as we crawl out of the Great

STRESS IS AN  
UNACKNOWLEDGED  
EPIDEMIC,  
THE TRUE SCALE  
OF WHICH  
IS STILL  
UNKNOWN.



Recession, just about everyone feels like they're doing more for less—and they probably are. Add to that the usual though no-less-daunting pressures of child rearing, elderly parents, education, health care, and finances, and you've got a population that's stretched pretty thin.

Since the 1930s, scientists have known that psychological stress has physical impacts, but in the past few years scientists have started to grasp the full extent to which this is true. Chronic stress is linked to depression and obesity. It raises the possibility of heart disease by 40 percent, and dramatically increases the chance of a heart attack or stroke. It can lead to dermatitis, contribute to Parkinson's, and boost susceptibility to rheumatoid arthritis and even certain cancers.

In our modern age, stress is an unacknowledged epidemic, the true scale of which is still unknown. And that's why we decided to make it

our cover story this month. To research this piece, contributing editor Brooke Borel sifted through dozens of studies to figure out how stress affects us and, more importantly, how we can address it in a smart and scientific way. I think you'll be pleasantly surprised at what she finds. At least, you'll have a good time reading it—and that should reduce some stress right there.

Enjoy the issue.

**Cliff Ransom**  
Editor in Chief

## Contributors



### William Gurstelle

Roman soldiers invading your backyard? William Gurstelle's interest in historical weaponry, machines, and defenses could help. For the first installment of his Manual column, History Fights Back (page 68), Gurstelle adapted a Roman-style catapult, simplifying it to make it easily replicable. Early tests worked a little too well: They attracted, rather than deterred, neighbors.



### Jonathon Kambouris

Assembling a sandwich is not usually deemed a feat, but photographing one suspended in midair for "Your Lunch Is a Sodium Bomb" (page 34) certainly is. Aided by food stylist Susan Ottaviano and a near-invisible combination of props, shelves, and wires, photographer Jonathon Kambouris built and sculpted each layer of the sandwich independently, then assembled them in a single shot.



### Daniel Grushkin

When writer Daniel Grushkin scans the room at scientific conferences, Suzanne Lee always stands out. Her unique style—which includes outerwear grown from microbial cultures—blends fashion and biotechnology. "She sits at an interesting intersection that people hadn't thought about until recently," says Grushkin. He profiles Lee in "Cultured Couture" (page 48.)



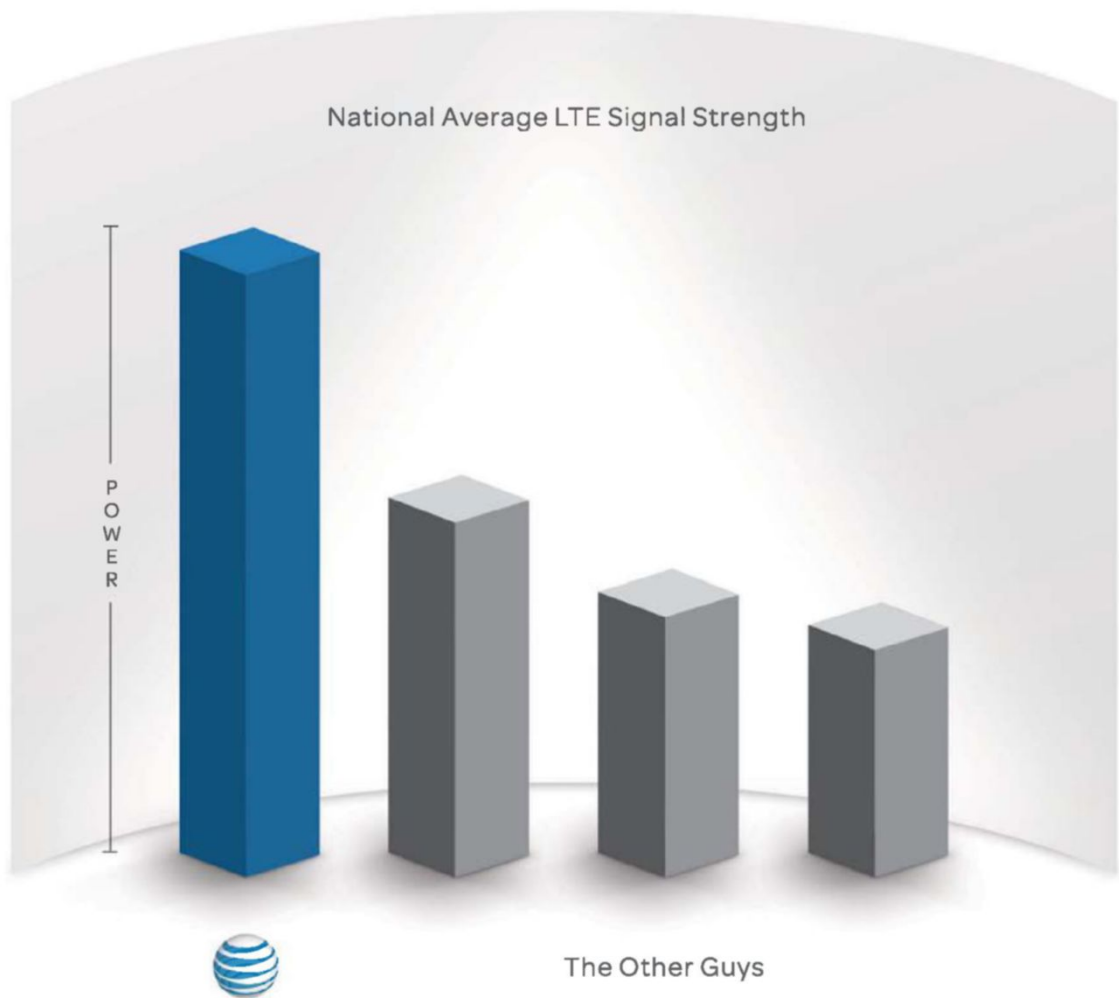
### Brooke Borel

While reporting this month's cover story, "The Science of Stress" (page 38), contributing editor Brooke Borel turned up a lot of misconceptions, the most surprising being that stress is all bad. Punctuated stress, as opposed to the chronic kind, can actually be healthy. For a freelance writer, Borel says, that came as a comfort, albeit a rather cold one the night before her deadline.



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## A Bit About Us

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# THREE THINGS THAT STRESSED US OUT THIS ISSUE

1

Hearing the story of how the world's tiniest sculpture [page 29] was lost forever due to one clumsy thumb smudge

2

Realizing that our passwords—no matter how complicated we try to make them—probably don't do much good [page 77]

3

Working around four holidays, one of the world's largest consumer technology expos, and an international auto show



## STRANGEST THING WE SAW AT THE CONSUMER ELECTRONICS SHOW

Of all the brilliant, amazing, crazy technology debuted at CES 2015, perhaps the strangest we found was Suitable Technologies's 18-foot-tall Beam telepresence robot. It lorded over the show floor, and made the regular-size Beam in our office look downright puny.

## UPDATES

### We've Created a Monster

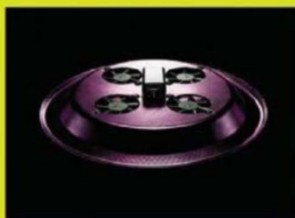
In the December 2014 issue, we gave Medrobotics Flex System (a bendable bot for throat surgery) a Best of What's New award. Now, the researcher who invented the underlying technology, Carnegie Mellon University's Howie Choset, has adapted it for a "Snake Monster." The robot's six serpentine legs use force feedback to climb over bumpy terrain.

### LEGO Braille Printer Gets a Boost

One of the LEGO projects featured in September 2014's Manual has received financial backing from Intel. Shubham Banerjee, now 13 years old, is poised to bring his braille printer to market. Banerjee prototyped the device using a LEGO robotics kit, and his new version will be powered by Intel's Edison platform.

## THE FUTURE IS NOW

In *Back to the Future Part II*, Marty McFly and Doc Brown zoom forward in time to 2015. And since we happen to be living in that particular year, we built a hovercraft to celebrate. Learn how to make your own on page 65.



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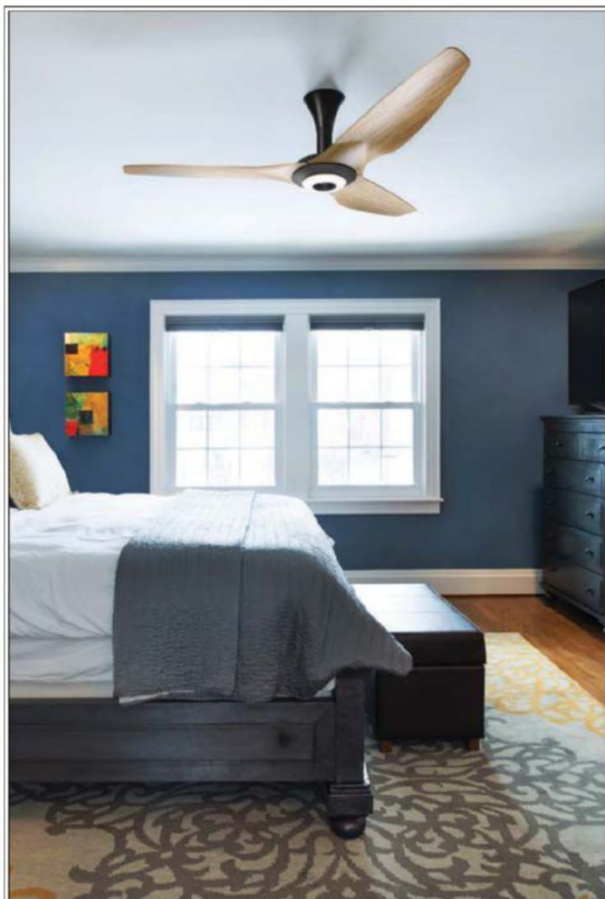


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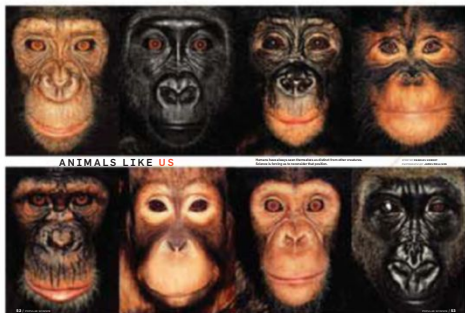
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## Peer Review



## ECHO CHAMBER

In his essay "Animals Like Us" [January 2015], Charles Siebert discussed the scientific investigation into personhood, inciting many responses, both for and against extending it to animals.

Even if chimpanzees, elephants, and other animals were as intelligent as humans, it wouldn't necessarily mean they should be freed. We don't guarantee that right to humans. Children are essentially captives and rely on caretakers, just as zoo animals depend on zookeepers. A chimp on the loose in New York would certainly die.

**Clive H. Walker**, Layton, Utah

I hope the Nonhuman Rights Project's efforts inspire us to consider the broader issue of speciesism. Using cognition as the metric to determine who is entitled to legal and moral consideration is a slippery slope. But as Jeremy Bentham wrote, "The question is not, Can they reason? nor, Can they talk? but, Can they suffer?"

**Nigel Osborne**, Toronto, Ontario, Canada

## LETTER OUT OF CONTEXT

**I prefer Lays Ketchup over Doritos, but whatever floats your boat. (They're better than you'd expect.)**

**Forrest Lu**, Mississauga, Ontario, Canada

## IMAGINATION AT WORK?

I enjoyed your January 2015 "Maker, Inc." article. But I find it ironic that GE is the one helping these domestic-manufacturing visionaries, particularly because under the leadership of Jack Welch, GE closed U.S. factories, "hollowed out" our manufacturing base, and moved offshore in search of cheaper wages to prop up its quarterly reports.

**John Sciarappa**, Eatontown, NJ

## HIGH AND NOT-SO MIGHTY

Like millions of Americans, I have hearing loss in the high frequencies but am far from deaf. A few years ago we had an electric range with an end-of-cycle signal for the oven you could hear most anywhere in the house. We now have a newer electric range, washer, dryer, and microwave with end-of-cycle beeps in such high frequencies I cannot hear them at all. Would it be too much to ask the experts from "Maker, Inc." [January 2015] to provide us all with a signal we can hear—and maybe even a volume knob?

**Carl Harber**, Columbia City, Ind.

## SLICK RECOMMENDATION

After last year's snowfall here in Michigan, I planned to upgrade my snowblower but was struggling to choose between a single- and two-stage model. Your article on the new Briggs & Stratton 922EXD two-function auger technology [Now January 2015] sealed the deal for me. I had one in my garage the next day. Of course, I've probably just guaranteed a snow-free winter.

**Loren Sztajer**, Troy, Mich.

A toy repaired with 3-D printing



## SHOW &amp; TELL

In January, we asked for your favorite 3-D printed projects.

**Josh Thom** said: "My three-year-old son, William, got a remote-control car for Christmas, but a wheel broke off the axle after 15 minutes of play. After I surveyed the damage, the prognosis wasn't great. But we could rebuild—better, stronger, faster, glow-in-the-darkier—thanks to our Printrbot. We designed a new wheel hub on paper, prototyped it in Tinkercad, printed it in PLA, and installed it in less than 24 hours. The car works great, William is once again elated, and one of the wheels now glows in the dark. 3-D home printing for the win!"

## SEND US PICS!

**Show & Tell:** Who says science and fashion don't mix? Certainly not designer Suzanne Lee (page 48), who grows her own clothes in a nutrient broth. Email a picture of your favorite science-inspired costume to [designbyscience@popsci.com](mailto:designbyscience@popsci.com) and tell us why it's awesome.



## HAVE A COMMENT?

Write to us at [letters@popsci.com](mailto:letters@popsci.com) or to *Popular Science*, 2 Park Ave., 9th floor, NYC 10016

## DISTILLING THE PAST

It's telling that Hackett's moonshine still [Rebuild, January 2015], which he made from materials found in a junkyard, can produce a clean, efficient fuel. Contrast this to what we're told by the professional super greenies, who say ethanol fuel is a bust. We haven't collectively applied our best minds to finding new and more efficient means to produce clean-burning ethanol. We need to seriously research this.

**B.P. Dumas**, Paragould, Ark.



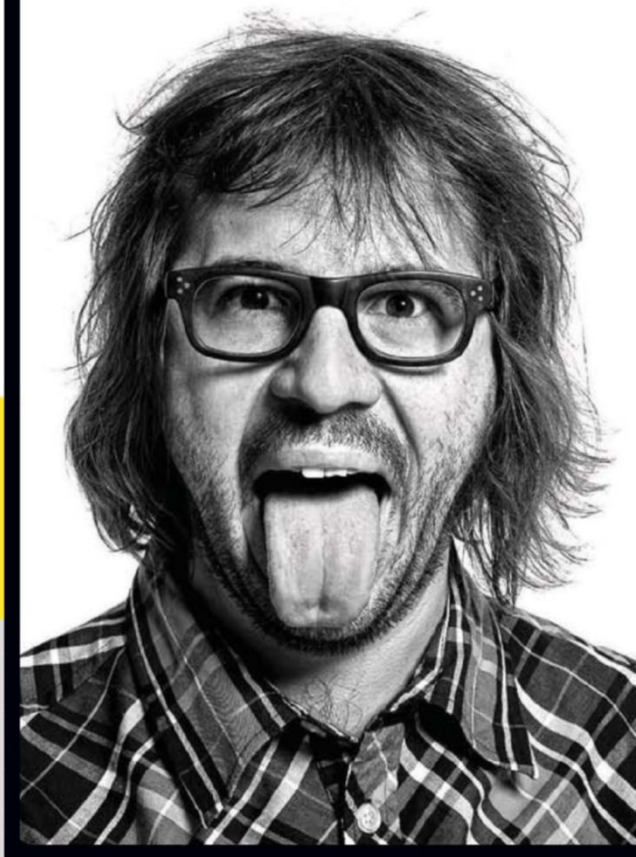
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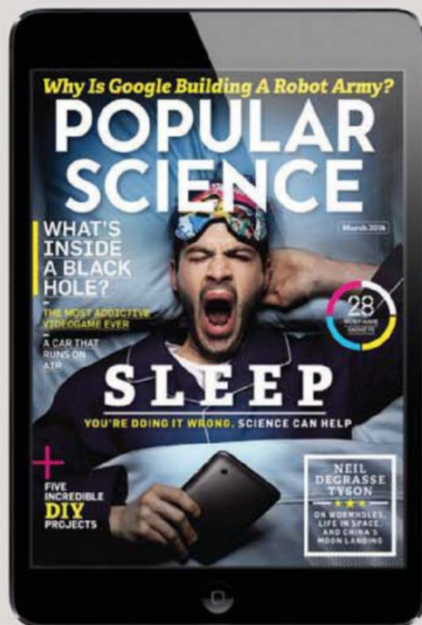
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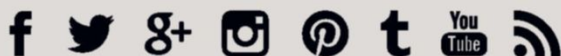
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EDITED BY **Michael Nuñez & Lindsey Kratochwill**

# Now

## Make Your Own Reality



**There's a growing** problem in the virtual reality (VR) industry: Filmmakers and game developers don't want to produce content for a headset few people have access to. And hardware manufacturers don't want to build accessories for headsets that don't have content. Razer's new open-source virtual reality (OSVR) platform could eliminate this catch-22, clearing the way for more VR experiments.

Using Razer OSVR, hackers and companies alike can build software that works on multiple VR operating systems and headsets. The platform supports popular video-game engines, gesture controls, and head-mounted displays (including industry leader Oculus Rift DK2).

Razer also released the OSVR Hacker Dev Kit, which comes with a modifiable VR headset. The kit ships with open-source hardware, and the circuit boards are modular, so they can be swapped out for new ones as they're released. Razer has also made OSVR's schematics readily available as a free download—so anyone can 3-D print or construct a headset.

The OSVR Hacker Dev Kit comes



### RAZER OSVR HACKER DEV KIT

#### Resolution

1920x1080

#### USB 3.0 slots

2 Internal

1 External

#### Release Date

June 2015

Price \$200

equipped with a 5.5-inch Full HD display, similar in size and resolution to the screen used in the Oculus Rift DK2, plus a sensor hub that includes an accelerometer, gyroscope, and compass to enable head-tracking. Although the development kit is geared toward the technically savvy, at such a low price point, most anyone can afford one—if for no other reason than catching a glimpse into the future of VR. **MICHAEL NUÑEZ**





# Obsessed

Some things are just . . . better

LINDSEY KRATOCHWILL

## 1 SIMPLICAM POWERED BY CLOSELI

This Simplicam security camera does more than indicate intruders. It identifies them. The device can remember 10 faces, so it can discriminate between a teen rummaging for a snack and a stranger. **\$150**

## 2 HELIOS SMART

Solar chargers sound great—until you wait around for hours for your iPhone to power up. Solpro's new device reduces that downtime by up to 300 percent, meaning it can fully charge a phone in 90 minutes with just the sun. **\$159**

## 3 RUST: THE LONGEST WAR

An insidious foe, rust has its way with much of the metal that makes up our world. Author Jonathan Waldman follows a pipe-cleaning robot through Alaska, crawls in an abandoned steel mill, and explores why corrosion wields such power. **\$27**

## 4 FLIC

In this era of taps and swipes, sometimes you need a good old-fashioned button. Or so think the folks at Shortcut Labs. The button can be tasked to order pizza, take photos, or share your location. **\$27**

## 5 BSXINSIGHT

Serious athletes determine fitness using lactate thresholds (the point in which lactic acid accumulates in the blood). Before

BSXInsight, a blood test was the only way to measure it. Now, the noninvasive wearable detects levels using LEDs. **From \$300**

## 6 BEER PEEN HAMMER

Though always vaguely connected, drinking and home repair finally come together in this hammer from Good Beer Hunting. The solid bronze tool can drive nails and open a beer. Whether that's a good thing remains a question. **\$55**

## 7 NANOGRID

Tired of tripping over tent stakes? BioLite's NanoGrid can shed some lumens on the campsite. It's anchored by a powerbank-lantern-torch combination, which can be charged via any USB power source—including the company's campstove. **\$100**

## 8 SPACE STATION RESEARCH EXPLORER

For anyone who has dreamed of life beyond the stratosphere, NASA launched the Space Station Research Explorer. The app takes visitors on a virtual tour of the ISS and allows them to take a peek at experiments. **Free**

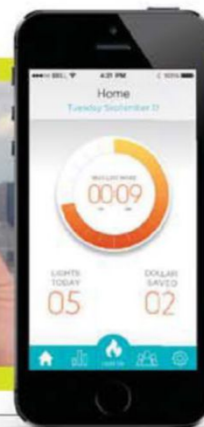
## 9 CHAPPIE

Neill Blomkamp's film follows Chappie, a robot that paints and writes poetry. But like any naive youth, Chappie is subject to bad influences—leading to potentially disastrous consequences. **March 6**



## 10 QUITBIT

Quitbit's heated coil lights your cigarette, and each time it does, the device takes note. A display on the lighter shows how long it's been since you last lit up, and an app tracks data over time. Sure, it's a little counter-intuitive, but the designers hope the lighter's little nudges will help smokers manage their habit. **\$99**



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# GUR KIMCHI WANTS TO DELIVER YOUR GOODS IN LESS THAN 30 MINUTES

EDITED AND CONDENSED BY LINDSEY KRATOCHWILL

**In December 2013**, Amazon CEO Jeff Bezos surprised viewers and announced on *60 Minutes* that his company is working on drone delivery. It seemed like a PR stunt, but since then, Amazon has run test flights, lobbied the Federal Aviation Administration, and listed drone engineer jobs. Few are closer to the project and better positioned to talk about its future than Gur Kimchi, vice president of Amazon Prime Air.

continued on next page →





## The Platform



**Popular Science:** Where did the idea of drone delivery come from?  
**Gur Kimchi:** I've been passionate about aviation all my life. So, something like drone delivery was never far from my mind. Amazon has been working on it for years, and in 2013, when we decided the technology was mature, we went public with it. We think it's going to change the game.

**PS:** How much are the drones able to carry?

**GK:** We're designing for the small UAV category. Our drone—plus everything connected to it—weighs less than 55 pounds. Each one can carry up to five pounds, and that represents as much as 80 or 90 percent of all items we sell.

**PS:** Where and when will we see the first drone deliveries?

**GK:** We will start making deliveries where we have infrastructure, such as fulfillment centers, and regulatory support. In terms of when—look, this is not that far. The future is sort of here. Drones are already being used for tasks such as crop monitoring and bridge inspection. We won't see broad adoption overnight, but we will get there, and we'll get there safely in the next few years.

**PS:** What will it be like to receive a drone delivery?

**GK:** I have three kids, and once when my wife was on a business trip one of the little ones woke up in the middle of the night screaming for a pacifier, which I couldn't find. I had a moment of panic. Do I wake up the other kids, load everyone into the car, and drive to a 24-hour pharmacy—if I can even find one? I got lucky and found the pacifier. But the better solution was for the pacifier to come to me. I imagine myself pulling out my phone, pushing a button, and 30 minutes later the pacifier shows up. It's not about people not wanting to make an effort; it's about people focusing on what's important to them at that

moment and having infrastructure to support that.

**PS:** When you talk to people about Prime Air, what's the usual reaction?

**GK:** In the beginning, people thought this was just science fiction. But in the last year, with the dialogue around it, it became a lot more mainstream. Even still people ask, "Wow, are you really doing this?" And I say, "Yes, this is my day job." You get into this disbelief and excitement cycle.

**PS:** What would you say to people who aren't excited, but worried?

**GK:** Well, people were distrusting of cars when they were first introduced; they didn't want cars to go faster than horses. But I think the other part of it is that for Amazon, safety is a main objective. I would reassure people that we won't release anything until we know this is a safe system.

**PS:** What are some of the technological barriers that you're wrestling with?

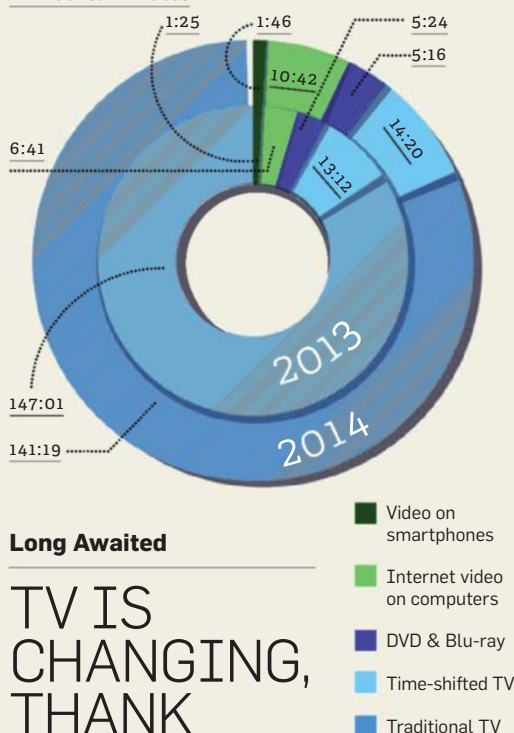
**GK:** One challenge we're working on is called "sense and avoid." The capability allows vehicles to operate safely and autonomously. There's an analogy that a member of my team, Amir Navot, came up with: We want drones to be more like horses and less like cars. If you're sitting in a car and driving toward a wall, the car will hit the wall. If you are on a horse and you ride toward the wall, it will stop on its own. We want to make drones independently safe, like the horse.

**PS:** How do you see the future of deliveries?

**GK:** Think of mobile phones—they teleport the Internet to us. We used to have to go to a desktop, sit down, and log on to access the Internet. Now, it comes to us, wherever we are. We're aiming to do the same for physical goods. Prime Air is trying to get as close as possible to real teleportation—without breaking the laws of physics.

## MONTHLY TIME SPENT BY MEDIUM

In Hours: Minutes



## Long Awaited

# TV IS CHANGING, THANK GOODNESS

**Just a few years ago,** watching TV in the U.S. was relatively simple: Pick from a handful of big cable or satellite companies, and plug in a television. Then along came Netflix, Hulu Plus, Amazon Prime Instant, and other streaming services, effectively turning smartphones, tablets, and computers into TV-watching machines.

The hype, of course, is these new services will spell the death of cable and broadcast, but the reality is a bit more nuanced—and it bodes well for anyone who loves TV.

First, though, a few facts: In 2014, the number of American households that rely on a broadband Internet connection rather than a cable or satellite subscription grew by 112 percent since 2013, audience research firm Nielsen reports. So yes, a certain group is streaming more. But, the majority of households is actually adding to traditional TV options. "Consumers hate to give up choice," says David Tice, senior vice president of media and entertainment at GfK, another market research firm. Last Fall, GfK

surveyed streaming media player owners and found that between 64 percent and 74 percent still had a paid TV service too.

So while cord cutting may not be all it's cracked up to be, another phenomenon is happening: Traditional TV and the Internet are becoming interchangeable as both offer more exclusive content on viewers' schedules. With more outlets, the competition for audience is that much more intense, so the quality of programming is rising. Netflix and Amazon have invested in original series, to critically acclaimed results (*Orange Is the New Black* and *Transparent*, respectively). And TV studios are moving their offerings online: HBO's stand-alone streaming app is due this year, and CBS released one last fall.

"Fifteen to 20 years from now, we may get to a point when all content is disaggregated and delivered over the Internet, and Comcast charges you twice as much for broadband," Tice says. For now, it means couch potatoes have more than ever to choose from.

**CARL FRANZEN**

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my phone, network  
and number for  
half the cost?**

**Connect the dots  
to find out.**

1



2



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# Stop Skids in Their Tracks

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Engine 3 or 4 cylinder

Horsepower 123 or 160

Fuel Economy up to 27 city, 37 highway

Price \$17,170



**There's nothing** quite like the sinking feeling you get when a car starts to skid. First comes the realization that your vehicle is not going where you want. Then, panic, as you desperately try to remember that driver's ed course (are you under- or over-steering?). Hopefully, you lay off the gas and brakes, and steer into the skid. Or you could use Ford's new Enhanced

Transitional Stability System (ETS).

Available in the 2015 Ford Focus, ETS predicts skids before they start. The system monitors a car's speed, steering wheel, and how a driver is turning, and it calculates the likelihood of a skid. If a loss of traction appears imminent, electronic stability control kicks in. While ETS is currently available in just one model, it's only a matter of time before Ford integrates it into others—and before competitors start doing the same. After all, a safer car is something that just about any driver would welcome. **MATTHEW DE PAULA**



## CAR NEWS YOU SHOULD CARE ABOUT

1

Single-speed EV transmissions will give way to two-speed units within 5 to 6 years, according to German supplier ZF. As with gas-powered cars, adding more gears to electric motors will make them more efficient, extending their range by up to 20 percent.

2

The Environmental Protection Agency is proposing to reduce the federal ozone standard for cars, power plants, and oil refineries from 75 parts per billion to between 65 and 70—a move it calculates will prevent between 710 and 4,700 premature deaths per year by 2025.

3

From January through November 2014, the average fuel economy for new light vehicles sold in the United States was 25.1 miles per gallon, according to trade publication *Wards Auto*. That represents a year-over-year increase of 1.8 percent, the first in four years.

4

Alcoa, the U.S. aluminum group, developed a new manufacturing process that makes it easier to create lightweight aluminum body panels for vehicles. The process changes the metal at the molecular level, making it 40 percent more formable.

## DESIGN OF THE MONTH



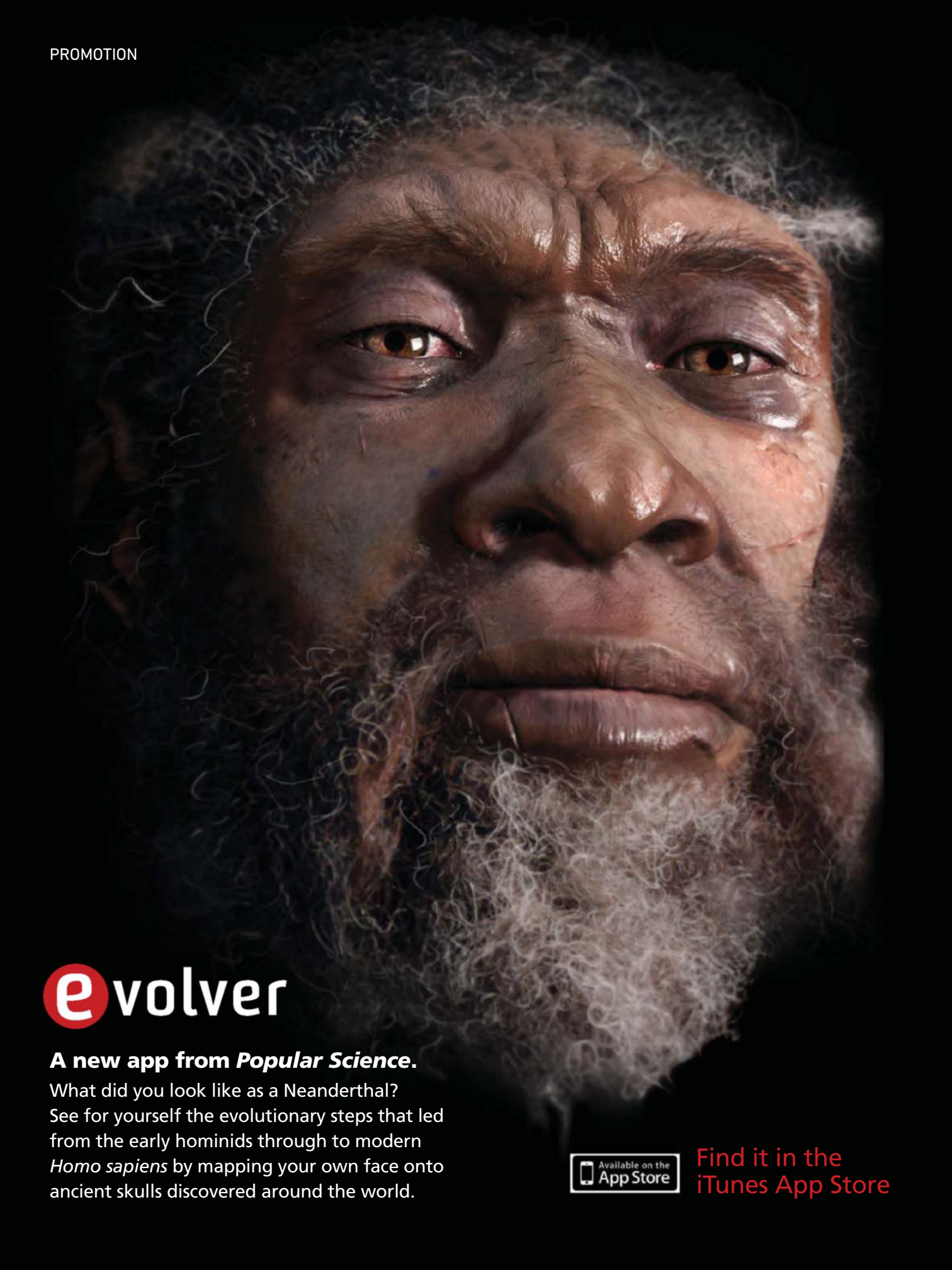
### Audi Prologue Concept

The interior of the Audi Prologue Concept is an homage to a world without buttons. Instead of the usual array of dials found on most dashboards, the Audi has three touch screens. There are no physical controls. The flexible OLED screen on the center console also actively bends toward the driver for easy access.

13

Number of hydrogen fueling stations in the United States. That number is projected to increase to 50 by 2017 as automakers, including Honda, Hyundai, Toyota, and others, work to bring fuel-cell vehicles to market.

PROMOTION



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**Trending**

**4.5**

Power consumption, in watts, of an Intel Core M processor, used in new, fanless hybrid devices

**11.5**

Power consumption, in watts, of an Intel Core i5 processor, found in standard premium laptops

# Tabtops? Laplets? We Love Them.



**Hybrid computers**—the laptop-tablet chimeras that include convertibles, detachables, and tablets with keyboards—always sounded better than they actually were. That's because they always came at a cost. Most hybrid devices were either powerful (and big as a breadbox) or slim (and grossly underpowered). For the average business traveler, hybrids could never really serve as a primary computer.

That was how things stood—at least, until late last year. In October 2014, Intel launched the Core M processor, which is built on a new energy-efficient architecture that allows it to draw less than half the power of its predecessor without sacrificing performance. Less power consumption means less heat, and less heat means no need for active cooling. As a result, a number of manufacturers are launching

lightweight, fanless, ultra-thin hybrid devices to go toe-to-toe with standard premium laptops.

Whether the hybrid movement will catch on remains to be seen. PC sales have slowed since 2011 as smartphone sales have soared. But, if you're one of the many people who still travel with multiple gadgets, having one less thing in your bag could come as sweet relief.

**RAFI LETZTER**



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Z20T  
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**Tested**

# We Ripped through a Car Door on Batteries Alone



**Ask any stonecutter or fireman** about the most important tool in their arsenal, and they'll likely tell you it's the cut-off saw. Designed to slice through steel and stone, cut-offs are the workhorse of many job sites—and they have an engine to match, gas-powered and heavy.

The TSA 230 STIHL Cutquik is the first battery-powered cut-off to hit the market. Without a combustion engine, it's nearly one-third the

weight of its gas-powered counterpart (down to 8.5 lbs from 25 lbs), a huge upside for emergency responders. It's also emission-free, so operators can use it indoors.

There's no question about the TSA 230's power, either. Its 36-volt battery spins the blade at 6,650 rpm while a built-in water line keeps the wheel cool and controls dust. Stihl's gas-powered cut-offs operate at about 5,000 rpm, so it's clear the TSA 230 has plenty of torque. The real question here is whether its battery will hold up over time. So we decided to put it to the test.

SAL VAGLICA

## The Test

We wanted to measure the TSA 230's battery in the most strenuous situations. First, we carved 1¾-inch concrete pavers, a standard for patio projects. Next, we cleaved off sections of ¾-inch angle steel (used to stabilize walls). Then, we halved 1½-inch steel padlocks—the ones most commonly cut by fire departments. Finally, we decided to up the ante and cut a car door in half. To determine performance, we counted the number of cuts it took before a fully charged battery drained.



## The Results

### CONCRETE PAVERS:

45 cuts using a water-cooled diamond wheel  
**STEEL:** 19 cuts while using an abrasive wheel  
**LOCK:** 8.5 locks total. We sliced through the ¾-inch-thick shackle and the

1½-inch-thick body of each lock using an abrasive wheel  
**CAR DOOR:** Three cuts vertically across the length of a popular midsize American vehicle's door, excluding the window, using an abrasive wheel

### CONCLUSION:

The TSA 230 isn't great for daylong projects far from an outlet, but for quick cuts, the combination of power, weight, and size doesn't get any better. It's a great addition to any tool shed.

# 70

Maximum depth, in millimeters, of the TSA 230's cut

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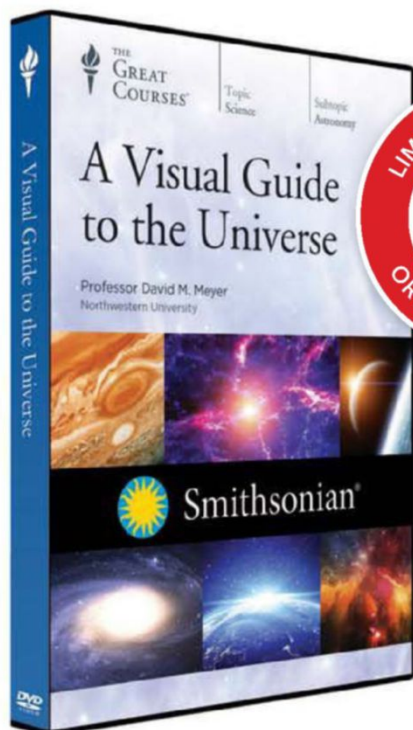
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EDITED BY **Jen Schwartz & Breanna Draxler**



Human hair



**The world's** smallest human figure, by artist Jonty Hurwitz, is only as tall as a sheet of paper is thick—just 100 microns. To “sculpt” it, he had nanoscientist Stefan Hengsbach direct long-wavelength light through a microscope onto a photosensitive polymer. This produced a single voxel, or 3-D pixel, at the focal point. Following a digital model, Hengsbach repeated the process to build the figure one voxel at a time. The hyperaccurate technique also has practical applications in medicine. For example, researchers can manufacture minuscule scaffolds for growing kidney tissue inside a patient’s body, eliminating the need for an organ transplant. **HEATHER HANSMAN**



# THE PANAMA CANAL'S MASSIVE UPGRADE COULD TRANSFORM GLOBAL SHIPPING. AGAIN.



**Over the past** 20 years or so, traffic on the world's oceans has quadrupled. Ships now carry 95 percent of the cargo imported to American shores. To move those goods more quickly and cheaply, cargo ships have grown nearly four times bigger—and many are now too large to fit through the Panama Canal.

A \$5.25 billion expansion project, scheduled for completion this year, will create two new lock complexes and a third lane of traffic. The new Panama Canal will be roomy enough for boats nearly three times the current maximum size.

Approximately 52 percent of container ships that leave Asia for the East Coast today opt to traverse the arguably less secure Suez Canal,

which cuts through Egypt to connect the Mediterranean and Red Seas. The Panama Canal's upgrade may soon bring the bulk of intercontinental traffic its way. The expansion will shake up shipping patterns and make trade more efficient by requiring less time, fuel, and money to get more products to U.S. ports—just as the original canal's opening did in 1914.

**REBECCA BOYLE**

Bigger boats sit deeper in the water, so construction crews dredged some 2 billion cubic feet of muck to make room.



## HOW IT WORKS

Traveling the Panama Canal involves nine steps, each of which will be upgraded in order to raise bigger ships from sea level up to lake level and back down again. **KATIE PEEK**

Progress as of December 2014 →

| 1                                                                        | 2                                                                     | 3                                                                     | 4                                                            | 5                                                                             |
|--------------------------------------------------------------------------|-----------------------------------------------------------------------|-----------------------------------------------------------------------|--------------------------------------------------------------|-------------------------------------------------------------------------------|
| <b>SEA LEVEL</b><br>Enter the canal at Port Cristobal                    | <b>0 TO 85 FEET</b><br>Rise through Gatun Locks                       | <b>85 FEET</b><br>Cross Gatun Lake                                    | <b>85 FEET</b><br>Pass through the lake's channels           | <b>85 FEET</b><br>Navigate the Culebra Cut                                    |
| A wider entrance will cut down on wait times, which can last a few days. | New, bigger locks will accommodate ships three times today's Panamax. | The lake's level will be raised two feet to boost reservoir capacity. | Deeper channels will enable navigation by new Panamax ships. | The cut connecting Gatun Lake and the Pacific locks will be four feet deeper. |

# 11,170,000,000

Tons of cargo that have traversed the Panama Canal since it opened in 1914, about 50 times the cargo U.S. ports handled in 2010



## FILLED TO CAPACITY

**Freighters are classified** according to how many 20-foot containers they can hold, measured in 20-foot equivalent units (TEU). Bigger vessels have enabled ever-more efficient ocean shipping over the past century.

### OLD PANAMAX 4,500 TEU

Built to take full advantage of the existing canal, these cargo vessels were already too small for the shipping industry by the mid-1990s.

### NEW PANAMAX 13,000 TEU

New Panamax ships, soon to be accommodated by the canal's larger locks, carry nearly three times as much cargo as their predecessors.

### GLOBAL MAX 19,000 TEU

The world's biggest boat, *China Shipping Container Lines Globe*, is longer than four football fields. It launched in November, and even the upgraded canal won't be able to handle it.



## A NEW CONTENDER IN NICARAGUA

**Just north of Panama**, the proposed \$50 billion Nicaragua Grand Canal would stretch 172 miles from Atlantic to Pacific, half of that through Lake Nicaragua, the country's largest source of drinking water. Chinese entrepreneur Wang Jing announced plans (and funds) for the canal last summer, and work began at the end of December. The canal aims to accommodate 18,000-TEU ships, capacity that Hofstra University geographer Jean-Paul Rodrigue and other critics say far exceeds demand, unless global trade doubles in the next few years. "Transportation is of course an enabler of trade," Rodrigue says. "But it's not the magic wand that creates it."

## A BIGGER, FASTER SUEZ

As Panama's eight-year upgrade wraps up, it's getting more competition. In August, Egyptian president Abdel Fattah el-Sisi announced plans to add another lane to the Suez Canal. The expanded waterway will accommodate two-way traffic, doubling its capacity from an average of 49 ships a day to 97, and cutting transit time from 18 hours to 11. It is ambitiously scheduled for completion in August 2015, making the two projects a race to the finish.

**6**  
**85 TO 54 FEET**  
Enter the Pedro Miguel Locks

Currently, ships nearing the Pacific encounter two sets of locks, separated by an artificial lake. A new Pacific access channel will bypass these steps altogether.

**7**  
**54 FEET**  
Cross Miraflores Lake

**8**  
**54 TO 0 FEET**  
Descend through Miraflores Locks

The locks on the Pacific side will be expanded to match the Atlantic's.

**9**  
**SEA LEVEL**  
Enter the Pacific Ocean

Dredging, completed in 2013, will make exiting the canal faster.

## ONE HELL OF A SHORTCUT

**It takes eight to 10 hours** to traverse the Panama Canal, plus 15 more while waiting on either end. That's still a lot faster than the shortest alternate ocean crossing, which tacks on some 3,000 miles. A freighter from East Asia, averaging 19 knots, could get to the Gulf of Mexico in 41 days going around Cape Horn or 43 using the Suez Canal. With the Panama Canal, the trip takes only 25 days, slashing time by 40 percent, not to mention fuel costs.



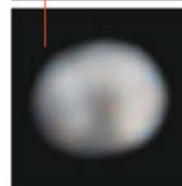
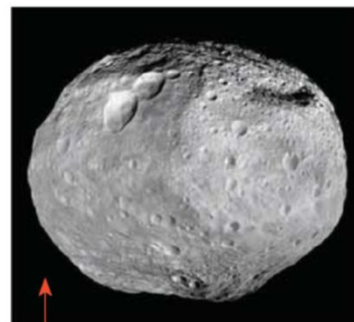
**Time Machine**

# Close-Up of an Ex-Planet

**This month**, the Dawn probe will give scientists their first clear view of dwarf planet Ceres. Like many objects in our solar system, it has a checkered past. Astronomers deemed the body a planet, then an asteroid, then a dwarf planet, all in the span of 200 years. The designation isn't up for debate on this mission. But if history is any guide, the term used to describe a rocky planetoid is still anything but solid. **KATIE PEEK**

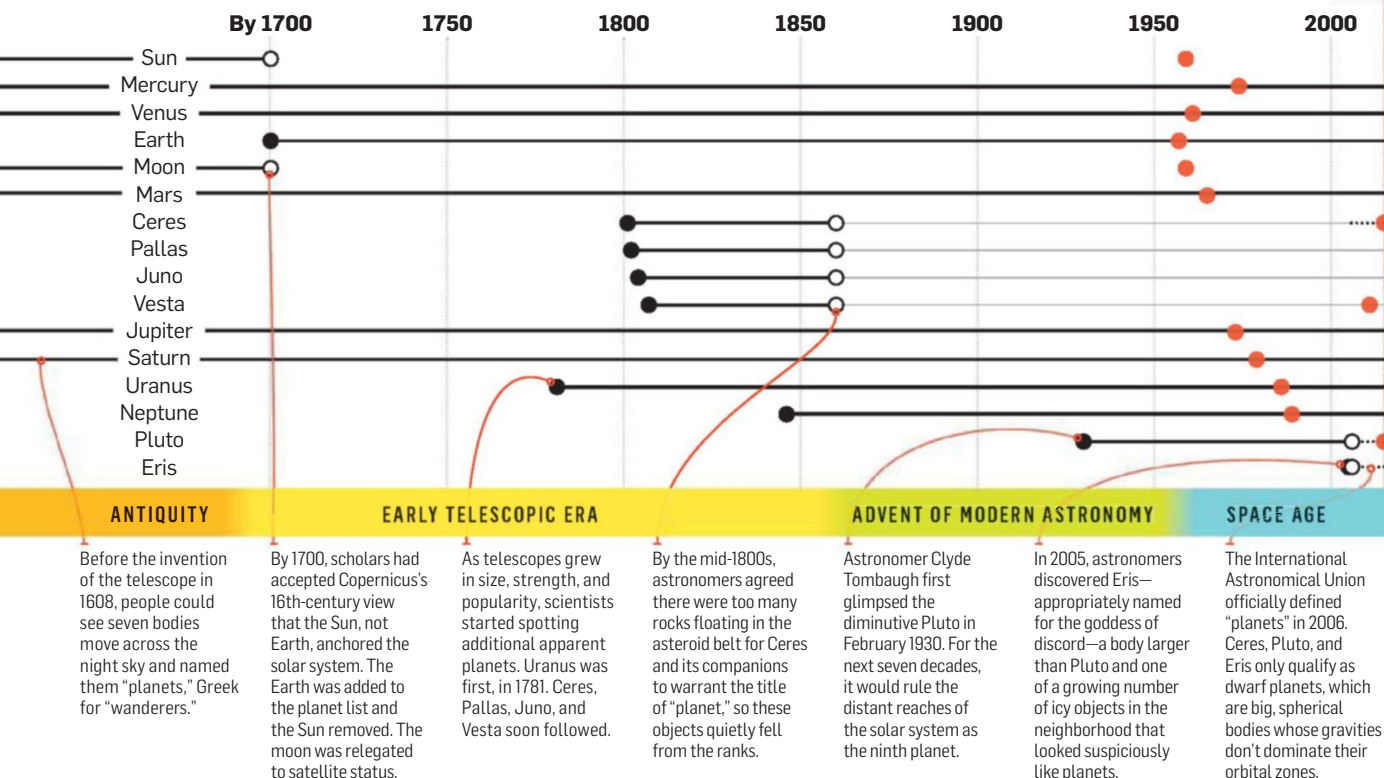
**KEY**

- Planet
- ..... Dwarf planet
- Asteroid
- Proclaimed a planet
- Lost planet status
- Received first spacecraft visit



Why visit Ceres when it isn't even considered a planet anymore? Compare Hubble's best shot of Vesta [left] to Dawn's [above].

**TODAY**



## DAWN'S DEEP-SPACE ENGINES

**Dawn will be** the first craft to orbit two deep-space bodies (Vesta, in 2011, and now Ceres) in a single mission—a feat made possible by its ion-propulsion engines. Instead of hauling heavy chemical fuel, Dawn relies on solar energy to charge atoms of xenon gas. Electrified metal grids push the newly formed ions into space at up to 90,000 mph, providing an

extremely low but constant thrust. (To approximate that force, tear out this page and rest it on your palm.) The craft accelerates gradually to high speed and uses far less fuel than a conventional rocket. Ion propulsion will enable increasingly ambitious exploration, says Marc Rayman, Dawn's chief engineer and mission director: "We're going to see a whole new world." **JUNNIE KWON**





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WIDE TB9018FWG



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TB9018MWG



PRPL/SLVR  
TB9018FWSP



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TB9018MRB



GRAY/PINK  
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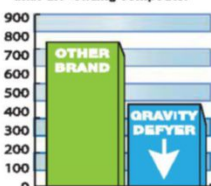


GRN/SLVR  
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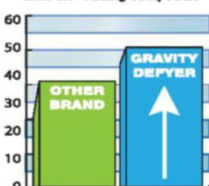


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**By the Numbers**

# YOUR LUNCH IS A SODIUM BOMB\*



**Americans love** their sandwiches. A recent USDA study found that 49 percent of adults eat one every day. "You're not going to get a quicker, more economical lunch. And sandwiches *can* be quite healthy," says Joan Salge Blake, a professor of nutrition at Boston University and spokesperson for the Academy of Nutrition and Dietetics. The problem, the study revealed, is that their sodium content has gotten out of control. A large steak sub from Quiznos, for example, contains 4,320 mg, almost twice the CDC's daily limit of 2,300 mg. The excessive sodium in oversize portions of processed cheeses, meats, and bread raises blood pressure and, along with it, the risk of heart disease. Unless you're buying low-sodium fixings, even a seemingly innocuous, homemade sandwich—such as the one at right—can take you past your daily limit. **BREANNA DRAXLER**



**25**

Percentage of total deaths in the U.S. caused by heart disease, about 600,000 annually

## \*Here's how to defuse it

"Today's takeout sandwiches are huge. Go back to the one your grandmother would have made. Keep the bread down to what a true serving is (60 to 70 calories). Add just a few slices of lower-sodium deli meat, and top it with what we really need, which is a variety of vegetables. Since they are very low in sodium, they can dilute out the higher-sodium items."

—JOAN SALGE BLAKE



More than half of the U.S. population—kids, adults over 50, African-Americans, and people with diabetes, hypertension, or chronic kidney disease—should aim for just 1,500 mg of sodium per day. That's equivalent to just two-thirds of this sandwich.



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# ARTIFICIAL INTELLIGENCE WILL NOT OBLITERATE HUMANITY

## It's not smart enough to turn sinister



**Elon Musk** is terrified of artificial intelligence (AI). The founder of SpaceX and Tesla Motors predicts it'll soon be "potentially more dangerous than nukes," and recently he gave \$10 million toward research to "keep AI beneficial." Stephen Hawking has likewise warned that "the development of full AI could spell the end of the human race."

# 2.5

Neurons, in millions, that researchers have simulated in a single AI system. A human brain has 86 billion.

Musk and Hawking don't fear garden variety smartphone assistants, like Siri. They fear superintelligence—when AI outsmarts people (and then enslaves and slaughters them).

But if there's a looming AI Armageddon, Silicon Valley remains undeterred. As of January, as many as 170 startups were actively pursuing AI. Facebook has recruited some of the field's brightest minds for a new AI research lab, and Google paid \$400 million last year to acquire DeepMind, an AI firm. The question then becomes: Are

software companies and venture capitalists courting disaster? Or are humankind's most prominent geeks false prophets of end times?

Surely, creating standards for the nascent AI industry is warranted, and will be increasingly important for, say, establishing the ethics of self-driving cars. But an imminent robot uprising is not a threat. The reality is that AI research and development is tremendously complex. Even intellects like Musk and Hawking don't necessarily have a solid understanding of it. As such, they fall onto specious assumptions, drawn more from science fiction than the real world.

Of those who actually work in AI, few are particularly worried about runaway superintelligence. "The AI community as a whole is a long way away from building anything that could be a concern to the general public," says Dileep George, co-founder of Vicarious, a prominent AI firm. Yann LeCun, director of AI research at Facebook and director of the New York University Center for Data Research, stresses that the creation of human-level AI is a difficult—if not hopeless—goal, making superintelligence moot for the foreseeable future.

AI researchers are not, however, free from all anxieties. "What people in my field *do* worry about is the fear-mongering that is happening," says Yoshua Bengio, head of the Machine Learning Laboratory at the University of Montreal. Along with confusing the public and potentially turning away investors and students, Bengio says, "there are crazy people out there who

## Are humankind's most prominent geeks false prophets of end times?

believe these claims of extreme danger to humanity. They might take people like us as targets." The most pressing threat related to AI, in other words, might be neither artificial nor intelligent. And the most urgent task for the AI community, then, is addressing the branding challenge, not the technological one. Says George: "As researchers, we have an obligation to educate the public about the difference between Hollywood and reality." **ERIK SOFGE**

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**THE SCIENCE OF**

**STRESS**

**EVERYONE'S GOT IT.**

**HERE'S HOW IT WORKS—AND HOW TO BEAT IT.**

**BY BROOKE BOREL**

**PHOTOGRAPHS BY SAM KAPLAN**



## ↓ Stressed out.

**Under pressure.** Run down. We tend to think of stress as a bad thing—and it can be. Traumatic experiences in early childhood can destroy mental health later in life, and chronic stress has been linked to illnesses such as cancer and diabetes. But stress can be good too. It helps us navigate an unpredictable world and determine which new experiences are good, bad, or dangerous. It also primes us to respond to similar situations in the future. The key with stress is to strike a healthy balance—getting enough at the right moments, but not too much overall. If the prospect of following that advice makes you tense up, take a deep breath: Science can help.

252

Number of LEGO Minifigure faces expressing anger, sadness, and fear, according to a study of the 627 different heads released between 1975 and 2010





**"STRESS IN THE  
BROADEST SENSE IS A WORD  
WE GIVE TO THE EXPERIENCES  
IN OUR DAILY LIFE, HOW WE  
INTERPRET THEM, AND HOW  
WE RESPOND TO THEM."**

—Bruce McEwen, neuroscientist, Rockefeller University

# THAT PANICKY FEELING

**Life is full** of stressful situations. Whether you've stepped in front of a speeding bicycle or are bombing a job interview, here's the chain reaction that's triggered.

1

## ALARM SIGNAL

When you hear, see, or otherwise perceive a threat, nerve signals whisk the message to your brain.

2

## BRAIN TRIGGER

The signals reach the amygdala—a brain region that helps with decision-making and the regulation of emotions. The amygdala in turn alerts the hypothalamus, which controls hormone production.

3

## HORMONE CASCADE

The fast-acting part of the nervous system releases adrenaline. Meanwhile, the hypothalamus produces corticotropin-releasing hormone, initiating a sequence that finishes with the production of the stress hormone cortisol.

4

## MESSENGERS

Cortisol, epinephrine (a.k.a. adrenaline), and other chemicals enter the bloodstream and travel throughout the body.

5

## THE KEY MASTER

Nearly all cells—in all organs and tissues—are studded with proteins called glucocorticoid receptors. Cortisol fits into them like a key to a lock.

6

## RESPONSE

Cortisol boosts blood sugar. Epinephrine makes the heart pound, increasing the oxygen flowing into major muscles. You're primed for fight or flight.



# DARWIN SWEAT IT TOO

**Stress exists** because it gives us an evolutionary advantage—for example, it allowed our early ancestors to dodge hungry predators. Today's version was shaped through natural selection; genetic variations

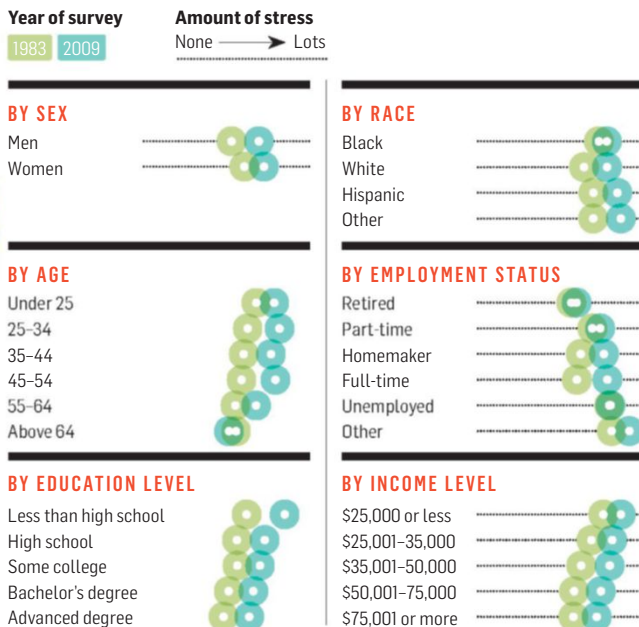
that gave certain individuals an edge were passed down through generations. But modern times bring new pressures, in part because society has become increasingly complex. "Each of us are members

of many different social groups, and each of them have different expectations of us," says Randolph Nesse, a physician and evolutionary biologist at Arizona State University. "All of them want more of our time

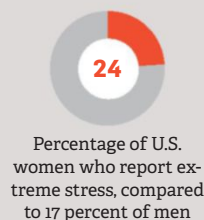
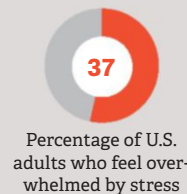
than we can actually provide." That's not to say we're more stressed than early humans. "Nero thought Roman times were stressful," Nesse says. Ours just involves trying to parse Facebook's privacy settings.

## WHO'S STRESSED?

**Most everyone**, but women more so than men and the unemployed more so than the retired. That's according to a study by a pair of researchers at Carnegie Mellon University, who asked Americans how much the unpredictable and uncontrollable cause stress in their lives. They compared their 2009 results with a similar survey taken nearly three decades earlier. The demographics vary, but one trend is clear: We're more stressed now than we were then. **KATIE PEEK**



## STRUNG OUT? YOU'RE NOT ALONE



People in Western and Southern states report more stress than those in the Midwest and East Coast.

## NAME THAT TENSION



### ACUTE STRESS (short-term)

Immediate threats trigger a fight-or-flight response. In addition to flooding the bloodstream with hormones, the body releases small proteins called cytokines, which help regulate the immune response. Until Firdaus Dhabhar, a neuro-immunologist at Stanford University, started studying their effects in the 1990s, scientists didn't understand that acute stress can actually enhance the immune system, improving your health.



### CHRONIC STRESS (long-term)

Everyday annoyances like heavy traffic or an overwhelming inbox—or sustained crises, such as unemployment or caring for a sick relative—can cause the body to activate the stress response constantly. The body and brain can't reset hormones and inflammatory chemicals to normal levels, damaging the immune system and making you more likely to get sick.

## SIGNS OF STRAIN

### HEART RATE

Your heart races in tense situations, which may be one of the reasons Tulane University researchers found heart attacks were three times as common in New Orleans post-Katrina.

### BLOOD PRESSURE

Notice that your forehead vein throbs when you're about to blow up? Stress boosts the force against the artery walls as the heart pumps blood.

### HORMONES

Changes in cortisol and other hormones register in your saliva, indicating not only stress, but according to a recent study, possibly also how well you respond to it.

### INFLAMMATORY MARKERS

Thinking about stressors can actually increase inflammation and the level of inflammatory markers, such as c-reactive protein, circulating in the bloodstream.

### ALLOSTATIC LOAD

A fancy word for the toll taken by all of your chronic stresses, as measured by the cumulative wear and tear on the cardiovascular system and other organs.





**“OUR BODIES CHANGE  
OUR MINDS, AND OUR MINDS CAN  
CHANGE OUR BEHAVIOR,  
AND OUR BEHAVIOR CAN CHANGE  
OUR OUTCOMES.”**

—Amy Cuddy, social psychologist at Harvard University

# GRIPES GET UNDER YOUR SKIN

**Chronic stress** stems from many circumstances, such as poverty, a bad marriage, or long-term ailments. Its repercussions—elevated cortisol levels and inflammation—can wear us out, from the cellular level on up to our major biological systems.

**B**

## CARDIOVASCULAR SYSTEM

Both chronic stress and stress-related disorders, such as anxiety and depression, increase the risk for heart disease, although scientists are not entirely sure why. According to the American Heart Association, stress may indirectly influence cardiovascular health through high blood pressure as well as unhealthy behaviors, including overeating and smoking. And the shock of sudden, intense stress, such as the death of a partner, can rapidly weaken the heart, possibly because of a surge of stress hormones. The phenomenon is called broken heart syndrome.

**A**

## NERVOUS SYSTEM

The brain changes in response to experiences and the environment. This is especially true in childhood, when key structures—such as the amygdala, involved in the fight-or-flight center—develop. Extreme childhood adversity can alter these structures and impact mental health later in life. An estimated 30 percent of anxiety disorders are linked to early trauma. Research from Columbia University shows that orphans who spent their early years in institutional care can have abnormally large amygdalae, physical changes that can persist even after adoption.

**C**

## DIGESTIVE SYSTEM

The brain and the digestive tract are in constant communication, says Emeran Mayer, a gastroenterologist at UCLA. Unsurprisingly, chronic stress is associated with painful gastrointestinal issues. According to Mayer's research, some patients with irritable bowel syndrome (IBS) show abnormal levels of cortisol and cortisol-stimulating hormones. People with IBS are also more likely to suffer from stress-related psychiatric disorders, including anxiety and depression.

30

Thirty percent of U.S. adults say stress strongly impacts their physical health; 33 percent say it strongly impacts their mental health.

33

E

## IMMUNE SYSTEM

According to research by Janice Kiecolt-Glaser, a clinical psychologist at the Ohio State College of Medicine, vaccines are less effective when we're stressed and wounds take longer to heal. Research from Carnegie Mellon University shows that stress even makes us more vulnerable to the common cold. In 2012, the scientists found a likely culprit:

In a healthy body, cortisol helps suppress inflammation. But the chronically stressed have consistently elevated cortisol levels, so the immune system grows resistant to the hormone, effectively ignoring it. Inflammation-causing proteins called cytokines—associated with developing a cold—then go unchecked.

D

## CELLS

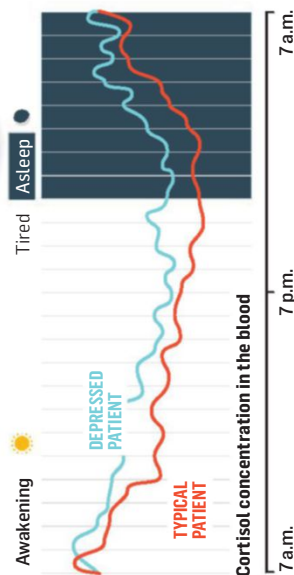
Nearly every cell has chromosomes, and the tip of each one is capped by a bit of genetic material; each time a cell divides, these telomeres shorten. When they run out, the cell dies. The chronically stressed have unusually short telomeres, putting them at risk for many age-related illnesses. The effects can be dramatic: In 2014, researchers found that disadvantaged 9-year-old boys had telomeres 19 percent shorter than those from more stable environments.

F

## METABOLIC SYSTEM

High cortisol levels boost the amount of fat around the belly. Extra abdominal fat may increase the risk for diabetes, which in turn may impair the stress response in the brain, says Antonio Convit, a psychiatrist at the Nathan Kline Institute for Psychiatric Research.

The system that inhibits cortisol in the brain doesn't work normally in people with type-2 diabetes. These patients also have blunted levels of cortisol when they wake up in the morning (see "How Does Stress Interfere with Your Sleep?"). As well as damage to the hippocampus, a brain region with concentrated cortisol receptors that is especially vulnerable to chronic stress.



## HOW DOES STRESS INTERFERE WITH YOUR SLEEP?

The **stress hormone** cortisol helps regulate sugar levels in the body. Cortisol levels vary throughout the day, but typically follow a circadian rhythm where they are highest in the morning, drop steadily, and then build up again overnight. Researchers from the National Institutes of Health found depressed patients tend to have abnormally high cortisol levels. Scientists still don't know what this means, but it points to one of the many ways that stress-related disorders may interact with and disrupt normal body cycles.





**"PEOPLE WHO ARE GENERALLY AMENABLE TO CHANGE DO THE BEST. THE RISK IS QUITE HIGH—A MISTAKE COULD BE MADE, AND THEN YOU'RE RETURNING WITH EBOLA. SO YOU'VE GOT TO UNDERSTAND YOURSELF WELL ENOUGH TO COPE."**

—Alex Kumar, an infectious disease doctor who volunteered with the British Red Cross in Sierra Leone

# WHEN THERE'S NOTHING TO DO BUT CRACK A CANCER JOKE

**Comedian Tig Notaro** had a famously stressful year in 2012. Within months, she got pneumonia, *Clostridium difficile* (an intestinal infection spurred by antibiotic use), went through a breakup, her mom died unexpectedly, and she was diagnosed with breast cancer. It doesn't exactly sound like comedy gold. But even before the shock had worn off, Notaro was airing her woes on a stage in Los Angeles. The now-legendary set killed. *Popular Science* recently caught up with Notaro to talk about finding the comedy in tragedy.

**PS:** At what point did you decide to turn this distressing series of events into material, especially since the trauma was so fresh?

**TN:** It wasn't a hard decision. I didn't feel like there was any other option. With everything that was on my mind, I couldn't just stand up on stage and go into some weird topic that

wasn't true. I was really hoping they would laugh, and—I mean, it was a rough night. There wasn't explosive, comfortable laughter start to finish. But there were also real belly laughs from the audience.

**PS:** Do you find comedy to be therapeutic?

**TN:** In the beginning of my horrible time in 2012, I kind of lost my sense of humor. I didn't identify with being a comedian. I felt very lost and confused. And it wasn't until my cancer diagnosis that I got my sense of humor back. It seemed so over-the-top to be diagnosed with cancer when I didn't have a mother or a girlfriend and I couldn't eat food. It seemed so insane it made me laugh.

**PS:** You still talk about the cancer and subsequent treatment in your sets. How else has your

comedy changed since 2012?

**TN:** I've allowed myself to be way more personal with the experiences I share. I've realized that—you know, it's so obvious and cliché, but people connect most with someone when things get personal. It hits harder when you're telling your own story.

**PS:** How does it feel to talk so openly about this stuff on stage?

**TN:** It carries a risk, and there is

a wave of stress that comes over me. But that's more excitement. I feel alive when I don't know what's happening. I think that is what being alive is. You have no idea what's around the corner, and I think if you can embrace that, there's no better feeling in the world.

*Notaro's upcoming documentary, Knock, Knock, It's Tig Notaro, airs on Showtime on April 17.*



## FUNNY OR DIE

A good laugh feels cathartic and that may not be a coincidence. Scientists are still learning how humor may help people cope with stress, but they do know that laughter boosts heart rates, breath rates, and oxygen consumption, and helps you relax. There is also some evidence that laughter may affect stress-related hormones. Researchers from Loma Linda University, for example, have found that elderly test subjects have lower cortisol levels in their saliva after watching humorous videos.

Humor may also be helpful for those in high-stress jobs. A 2013 study of 179 firefighters by psychologists at Indiana University and Purdue University suggested that humor buffers the effects of burnout and post-traumatic stress disorder. The type of humor may matter, too. In 2012, research by Shino Takaoka, a clinical psychologist at Kwansei Gakuin University in Japan, found that self-deprecating humor may be better at alleviating stress in women, while aggressive humor may have a negative impact on mental health in men.

## UNIVERSAL DEFENSE

**On tough days** it's easy to envy your dog, but all life, in fact, needs some form of a stress response to deal with its environment.



### FUNGI

Fungal pathogens use chemical signals to handle stressors, including salts (which suck water from their cells) and toxic materials (which can strain their protective membranes).



### MONKEYS

Macaques with low social status express genes associated with stress hormones and inflammation, and have fewer white blood cells. When their rank improves, so may their health.



### RODENTS

In the laboratory, both mice and rats briefly produce pain-inhibitors when they smell human males—but not females. That may skew experimental data collected by men.



### BUTTERFLIES

When exposed to extreme temperatures in their chrysalis stage, butterflies release cold-shock hormone and steroids—which may be what gives their wings unusual colors.



### PLANTS

When a leaf gets chewed, the plant increases production of hormones called jasmonates, which help heal wounds. Volatile versions of the compounds also warn nearby relatives of pending danger.

## QUIZ: HOW STRESSED ARE YOU?

**Afraid of needles?** Pick up a pencil. In addition to drawing blood to check for stress markers, scientists craft quizzes to reveal whether you're feeling harmful stress. This one was adapted from the Perceived Stress Scale by Sheldon Cohen, a psychoneuroimmunologist at Carnegie Mellon University.

In the past month, how often did you...

| QUESTION                                                         | SCORE                                                                                                                                             |
|------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| 1 Feel upset because of something unexpected?                    | <b>SCORING FOR QUESTIONS 1-6</b><br>NEVER 0 POINTS<br>ALMOST NEVER 1 POINT<br>SOMETIMES 2 POINTS<br>FAIRLY OFTEN 3 POINTS<br>VERY OFTEN 4 POINTS  |
| 2 Feel unable to control the important things in your life?      |                                                                                                                                                   |
| 3 Feel nervous or stressed?                                      |                                                                                                                                                   |
| 4 Feel angry because things happened that you couldn't control?  |                                                                                                                                                   |
| 5 Feel you had so many troubles that you couldn't overcome them? |                                                                                                                                                   |
| 6 Find yourself unable to cope with your responsibilities?       |                                                                                                                                                   |
| 7 Feel confident that you could handle your personal problems?   | <b>SCORING FOR QUESTIONS 7-10</b><br>NEVER 4 POINTS<br>ALMOST NEVER 3 POINTS<br>SOMETIMES 2 POINTS<br>FAIRLY OFTEN 1 POINT<br>VERY OFTEN 0 POINTS |
| 8 Feel that things were going your way?                          |                                                                                                                                                   |
| 9 Feel able to control irritations in your life?                 |                                                                                                                                                   |
| 10 Feel you were on top of things?                               |                                                                                                                                                   |

### Add your points.

Scores of 13 are considered average; scores of 20 or higher are considered high stress.

(See page 46 for management tips.)





**"WE COMBAT STRESS MOSTLY BY PREPARATION. IT'S A BAD DAY WHEN YOUR ROBOTIC ARM FREEZES AS THERE'S A SPACEWALKER RIGHT ON THE END, BUT IT'S SOMETHING YOU KNOW HOW TO DEAL WITH FROM TRAINING."**

—Michael Barratt, NASA astronaut and space medicine specialist

# HACKS FOR BETTER HANDLING HANGUPS

A little stress can be a good thing, but it's important to keep it under control. These six strategies will help you retain your Zen.



1

## BOUNCE BACK

Some people are naturally resilient, but it's also a learned skill. Stress inoculation gradually exposes people to stressful situations so they develop calmer reactions. Elizabeth Stanley, a security studies expert from Georgetown University, uses this training to help soldiers prepare for high-stress missions. And a 2014 study from Islamic Azad University in Iran suggests the technique can help civilians too.

2

## SAY OM

It sounds cliché, but mindful meditation, breathing exercises, and introspective tasks like gardening or running lower stress, says Steve Hickman, a clinical psychologist at the University of California, San Diego. These methods can actually cause physical changes: A 2014 study from the Ohio State College of Medicine suggests that breast cancer survivors who practice yoga have lower levels of stress-related cytokines.

3

## GET MOVING

Visit your doctor for advice, and you'll inevitably hear that you should hit the gym. "Both aerobic and nonaerobic exercise have been shown to reduce stress," says James Blumenthal, a psychologist at Duke University. It can also help treat some cases of clinical depression. A 2013 study by Princeton University researchers suggests that, at least in mice, exercise blocks stress responses in the hippocampus.

4

## POP A PILL

No medication completely blocks stress—we wouldn't want it to. But treatments exist for severe stress-related disorders, including drugs that inhibit brain chemicals in patients with depression and tranquilizers that reduce anxiety. And a clinical trial on cholinesterase inhibitor, a chemical that may make the brain more plastic and thus able to learn better stress responses, is underway at Harvard University.

5

## SOCIALIZE

Family and friends help buffer the negative effects of experiencing conflict, says Sheldon Cohen, a psychoneuro-immunologist at Carnegie Mellon University who studies how social networks mitigate stress. In 2014, Cohen and colleagues published research showing that healthy adults with strong social support—people who regularly received hugs—were less likely to succumb to the common cold.

6

## WALK AWAY

It's not a good idea to avoid your problems, but a short break can help manage stress. A 2013 study from the University of Toronto showed that college-age test subjects who purposely shifted their attention away from the pressures of work, school, and family were more adept at coping, compared with those who pretended their stress would simply disappear on its own.

# THE SECRET TO RESILIENCE

**Some people** recover from trauma and tragedy more quickly than others—for example, around a quarter of war veterans develop post-traumatic stress disorder, while many of their peers who saw similar violence do

not. Researchers are still trying to unravel why, but the answer may be partly embedded in our cells. Neuroscientists at the Icahn School of Medicine at Mount Sinai have shown that mice especially resilient

to stress have increased levels of a protein called beta-catenin, which acts in a reward center called the nucleus accumbens. They have confirmed their findings in post-mortem human brain tissue from

people who suffered from depression, a stress-related disorder. The work may eventually lead to new therapies for depression and other stress disorders that help chemically bolster resilience.

## A TOTALLY UNSCIENTIFIC STRESS MONITOR REVIEW

There are gadgets to measure everything from what we eat to how many steps we take—and now, a new breed of devices claims to monitor stress. I tested three over the course of a week. The result? Not all stress monitors are created equal.



### 1 GALVANIC: THE PIP, \$224

**How it works:** Two gold-plated sensors detect stress-induced electrical fluctuations in the skin eight times per second. The device connects to a smartphone via Bluetooth, and comes with several apps. One measures stress over a period of time; another is a racing game where a character (in this case, a dragon) adjusts its speed as you relax.

**My take:** The device is handheld, so it was hard to remember to use it. The first app usually left me feeling antsy and I never got the second to work. The data was bare bones and hard to interpret, although it did show I was 100 percent relaxed after a massage—which was true.

### 2 ZENSORIUM: TINKER, \$120

**How it works:** A handheld unit plugs into the bottom of your phone. Optical sensors scan the thumb to measure heart rate and variability, respiratory rate, and blood oxygen. The app offers two options: Vita, which measures fitness based on heart and respiratory rates and blood oxygen, and Zen, which includes a breathing exercise and measures heart rates.

**My take:** The design is slick, but measurements were hard to make. Each time I plugged the Tinke in, I had to remove my iPhone case. My best Zen score came right after yoga; oddly, my best Vita score came after a glass of boozy eggnog.

### 3 SPIRE: SPIRE TRACKER, \$150

**How it works:** A wearable Bluetooth device clips to a waistband or bra, and proprietary sensors and algorithms measure breath patterns that betray stress. Spire is also an activity tracker, and flags bursts of time when the user is particularly tense, calm, or focused.

**My take:** It was the only wearable device, and the easiest for tracking stress over time. After some snags during setup, the app was the best at detecting my mental state. In the minutes before a stint as a guest speaker, I got a message suggesting a mind-clearing exercise.

## STRIKE A POSE

**Your posture** might influence how you experience stress. Researchers at Columbia University found that people who stood or sat for just two minutes in expansive positions—with arms and legs taking up more room—had lower levels of cortisol and higher levels of testosterone compared to those who held guarded poses. They also felt more powerful.



## EAT YOUR WAY TO CALM

**The microbes** that live in and on our body—collectively called the microbiome—seem to play an intriguing role in human health, influencing ailments from chronic skin rashes to diabetes. A growing body of research suggests the microbiome may also affect mood and behavior. Separating a rat from her pups, for example, can lead to changes in intestinal flora as well as anxious behavior, and there is evidence that animals with low levels of gut microbe diversity have an overactive stress response in the brain.

Eventually, such work may lead to microbe-boosting cocktails for stress-related ailments such as depression or irritable bowel syndrome. But John Cryan, a neuroscientist at University College Cork in Ireland who is studying the microbiome, says calming probiotic smoothies aren't yet on the horizon. "There are so few human studies right now," he says. "The food companies aren't paying for them. And the neuroscientists are slow to move into this field."





CULTURED  
• ✂ •  
COUTURE

SUZANNE LEE  
WANTS TO  
GROW CLOTHING  
IN A LAB

BY DANIEL GRUSHKIN









# FASHION DESIGNERS

*DON'T USUALLY GIVE*

*TOURS OF BIOLOGY*

*LABORATORIES,*

*BUT ON A RAINY DAY*

*THIS FALL, DEEP IN AN*

*INDUSTRIAL COMPLEX*

*ALONG THE BROOKLYN*

*WATERFRONT,*

Suzanne Lee guides me through the warren of labs that make up Modern Meadow. Lee recently joined the biotech start-up as its creative director. Beneath her white lab coat she wears leather pants and a neoprene shirt with a lightning bolt. When I ask what exactly a creative director of a biotech start-up does, she points to a plastic bracelet that encases the husks of three beetles. "Nature is the best designer," she says. Her job is to make it ready-to-wear.

I follow Lee down fluorescent-lit hallways in the Brooklyn Army Terminal. Since moving in last year, Modern Meadow shares its corner of the complex—at one point the military depot that deployed Elvis Presley—with a company developing an HIV vaccine. The sterile conditions necessary for immunotherapy research make the environment ideal for Lee's work too. She stops in front of a fridge-size incubator set to 98.6°F, body temperature. Behind the gray door, she explains, bovine cells are dividing and fusing into a dense material similar to cow hide. Lee, in other words, is growing petri plates of leather.

"Imagine leather that's as lightweight and transparent as a butterfly wing or has the natural stretch of rubber," Lee

says. "Or imagine a material with the dynamic responsiveness of the skin of a chameleon." In nature, such qualities arise from the spontaneous assembly of biological cells. By manipulating cell cultures, scientists at Modern Meadow can customize a material's strength, texture, weight, and elasticity. It's an idea Lee hopes will take fabric—and with it fashion—in an entirely new direction.

Lee can recall the exact moment her creative pursuits collided with the world of microbiology. Ten years ago, while a senior research fellow at the art school Central Saint Martins, in London, she had a chance encounter with Scottish biologist David Hepworth. She was writing a book about how science and technology could influence fashion, and when she told him about it, Hepworth introduced her to the concept of living materials. He described how organisms like bacteria, and not just plants like cotton, could grow cellulose—the most common fiber in the world.

After talking, Lee and Hepworth decided to collaborate on a fashion experiment. They started with tea, then added sugar and microbes, the same bacteria and yeast used to ferment the vinegary health drink kombucha. The microbes eat the sugar and spin cellulose into a dense nano-scale mesh. Although it looks like a gelatinous mat (known as the mother when making kombucha), it's dozens of times stronger than most fabrics.

They grew the material at home, Lee in her bathtub and Hepworth in his garage. As it dried, it stiffened into a tough substance akin to leather. Lee found it absorbed plant dyes more easily than normal fabric. Also, if she draped the wet material around a dress-form it would knit itself together so that it had no seams at all.

"You can actually have a dress growing in a vat of liquid," Lee says. "I had never imagined a piece of clothing could be alive. And I have nothing to do with its creation. It's growing for me."

Lee made a collection of coats using the microbial cellulose: a bomber jacket, a denim-style jacket, a biker jacket. Although the designs were conventional, they looked otherworldly and slightly translucent. "Production from bacteria is so alien," she says, that she wanted to create familiar garments to show it wasn't so strange.

As Lee worked on her couture pieces, others began to see opportunity in biomaterials as well. Bolt Threads, for example, began engineering microorganisms to produce spider silk. It's now one of several start-ups attempting to use molecular biology to manufacture fibers similar to scarce natural ones. "What's fundamentally changed is our ability to look at materials in nature and say, with a straight face, that we can potentially make them with biotech," says Dan Widmaier, Bolt Threads's chief executive officer.

That could benefit fabric manufacturers, but more importantly, it could benefit the environment. Most existing materials have a significant downside: Cotton farming typically uses intensive pesticides, and synthetic fabrics such as polyester are made with petroleum. The roughly 14

# Grow Fabric in Your Kitchen

The microbes used to brew the drink kombucha can also produce a strong, leathery cloth—no cow required. Use Suzanne Lee's recipe to make your own.

## Materials:



200 milliliters  
of organic  
cider vinegar



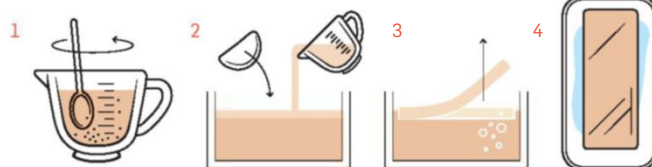
200 grams of  
granulated  
sugar



1 live  
kombucha  
culture



2 green tea  
bags



## Directions:

**1. Brew the liquid:** Boil 2 liters of water, and steep the tea for 15 minutes. Remove the tea bags and add the sugar, stirring until it's dissolved.

**2. Prep the culture:** Make sure the liquid is cooler than 86°F, and then pour it into your container. Add the cider vinegar and the kombucha culture. Cover the container with a cloth.

**3. Harvest the mat:** While it grows, the mixture should be kept at room temperature. First, the culture will sink to the bottom. You'll know fer-

mentation has begun when bubbles and a transparent skin start to form at the surface. Over time, the culture will rise to the surface and accumulate in a thick layer. Once the mat reaches 2 centimeters in thickness (around three to four weeks), take it out of the container and gently wash it with cold, soapy water.

**4. Dry the material out:** Spread the sheet flat on a wooden surface. When it no longer feels wet, you can cut and sew it like any other fabric.

**NOTE:** This recipe will produce a piece of microbial leather as large as 7 x 6 inches, and it will take the shape of the container you put it in. To grow a larger or smaller sheet, adjust the proportions accordingly.

billion square feet of leather produced from bovines annually, according to the Food and Agriculture Organization, requires millions of animals, consuming billions of gallons of water and pounds of feed a day—to say nothing of the methane emissions. “So it seemed to tick all the boxes,” Lee says of her fabric. “Use less water, hell yeah. Low energy, absolutely. Less chemicals, less dyes. Throw it in the garden when you're finished with it.”

Lee founded a design consultancy called Biocouture in order to accelerate the development and adoption of new biological materials. But she knew scaling her own product would be an enormous challenge, as would engineering necessary functions like greater elasticity and water resistance. So when her work caught the attention of Andras Forgacs, co-founder of Modern Meadow, she was open to collaboration. The company was attempting to use the tools of regenerative medicine to manufacture meat from bovine cells, and in 2013, Forgacs invited Lee to lead its initiative to produce leather. It would be a departure from her experiments with microbial cellulose, but an opportunity to work with a team of scientists. She quickly signed on.

From her position at the intersection of biotechnology and the fashion industry, Lee has become increasingly confident in the future of biofabrics. She sees athletes searching for a performance edge and fashion designers hunting for surprising new materials as the earliest adopters. In the long term, she envisions dynamic clothing that reacts to our bodies like a second skin. “Imagine the garment having a layer of living cells that feed off your dead ones to clean and repair itself,” she says. “Or it could sense your body

temperature, and when you're cold the cells might reorganize, just as feathers and fur fluff up to act as insulators.”

In December, representatives from at least 25 start-ups joined Lee in New York City for Biofabricate, a summit she organized for people working on new biomaterials. Held in Microsoft's offices, the conference hosted a pop-up lab with a slew of new products, including bricks grown from fungi and prints using engineered bacteria. “Suzanne Lee is at the forefront of experimentation and innovation,” says Paola Antonelli, a senior curator at the Museum of Modern Art and one of the presenters at Biofabricate. “People can wear a scientific revolution and contemplate in a mirror whether its disruptive potential suits them.”

But first, Lee has to actually grow leather in a lab, and not even that may convince everyone of its value. Oron Catts, an artist and tissue engineer who grew a tiny lab-leather jacket as a critique of biotechnology, argues that cultured material obscures rather than solves sustainability problems. “Western technology is getting better and better at hiding the victims of our consumption,” he says. But he adds: “I'm more than happy to be proven wrong.”

For now, Modern Meadow remains tight-lipped about its actual progress, and the only evidence of leather I see during my trip to the Brooklyn Army Terminal are shoelace-thin strips floating in test tubes. But when Lee looks around the lab, surrounded by pipettes and fume hoods, flasks and centrifuges, she doesn't seem at all daunted by the enormity of the task ahead. “This is potentially revolutionary,” she says, then laughs. “Oh lord, there's a fashion designer trying to save the world.”



THE  
2015

# vizzies

We honor outstanding visualizations from the worlds of science and engineering. Information has never looked so beautiful.



The best visualizations communicate complex subjects with evocative images, enlightening illustrations, and engrossing interactive media—all things we value tremendously at *Popular Science*. So we're especially pleased to partner with the National Science Foundation to award the Vizzies. The international competition, which the agency has led for more than a decade, recognizes the finest illustrations, photographs, videos, graphics, and apps, whether produced by academic researchers, artists, or hobbyists. Without further ado, here are the honorees.

THE EDITORS

Reporting by Alexandra Ossola, Neel V. Patel, and Katie Peek

## HOW WE CHOSE THE WINNERS

During two rounds of judging, science and visualization experts at the National Science Foundation and *Popular Science* winnowed 303 entries to 50 finalists, 10 in each category. To arrive at the Experts' Choice, a panel of final-round judges rated the visualizations on their artistic merit and communication excellence. Readers voted online for the People's Choice. Each of the winners was vetted for accuracy by independent experts.

### FINAL-ROUND JUDGES

**David Bolinsky**, medical animator and co-founder of e.mersion studios

**Bennett Foddy**, professor of game design at New York University's Game Center

**Soraya Gage**, general manager of NBC Learn, an NBC News division

**Lena Groeger**, science journalist and news apps developer at ProPublica

**Robert Kosara**, research scientist at Tableau Software

**Marcia Rudy**, special exhibitions and programs at the New York Hall of Science

**Rita Teutonico**, executive associate director of the School of Environment, Arts, and Society at Florida International University

**Jan Willem Tulp**, head of the data visualization studio TULP Interactive

THIS PAGE, FROM LEFT: COURTESY RYAN CHEN; COURTESY TED KINSMAN AND JOSH SHAGAM; COURTESY BERNARDO CESARE; COURTESY LARRY HOWELL; COURTESY ROBERT E. CLARK; COURTESY JACOB ZWART; PATRICK KELLY, CJ HUMES, AND SHAYNA MCCARTHY; COURTESY GAZZALEY LAB

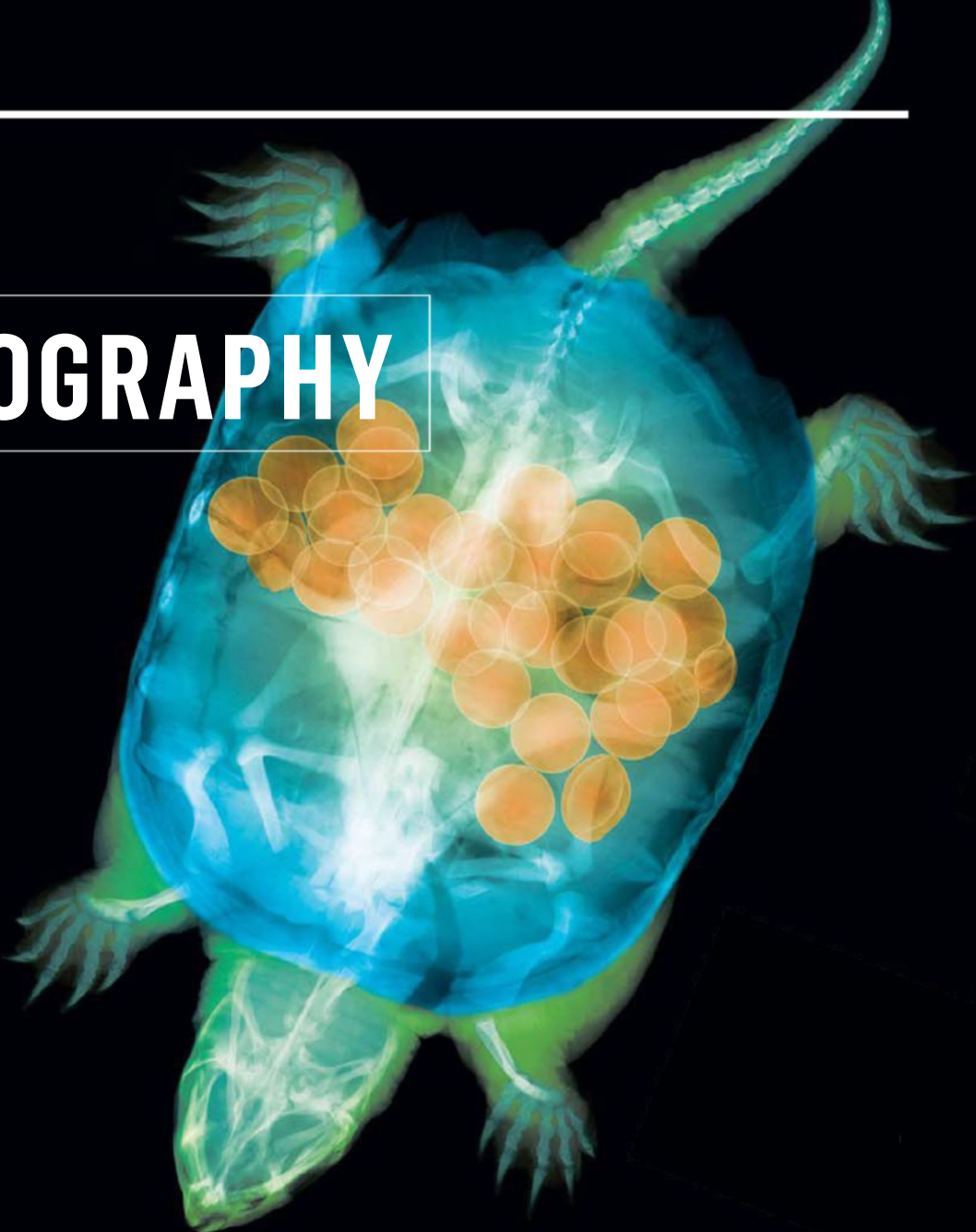
# PHOTOGRAPHY

## EXPERTS' CHOICE

### FALSE-COLOR X-RAY OF A SNAPPING TURTLE

**Ted Kinsman**

When Ted Kinsman picked up this specimen on the side of the road one spring morning, he was hoping to get a good X-ray image of a snapping turtle. But after he placed the turtle in the X-ray machine, Kinsman was surprised to see it had about 30 eggs hidden inside. He added false color to the image to accentuate them. A professor of photographic sciences at the Rochester Institute of Technology, Kinsman has been capturing images of local wildlife for the past decade—sometimes living creatures, but more often dead ones, like this expired turtle. His students aren't surprised, he says, to find road kill in his lab's freezer.



## PEOPLE'S CHOICE

### ALCIAN BLUE AND ALIZARIN RED CHAMELEON

**Elizabeth Marchiondo and  
Andrew Gillis**

Photographer Elizabeth Marchiondo doesn't often have the opportunity to handle organisms as delicate as this chameleon. "I'm used to photographing live aquarium scum through a microscope or wading through a

lagoon to capture specimens," she says. So Marchiondo was delighted when zoologist Andrew Gillis donated the deceased creature to the lab where she was a microscopy intern. The chameleon had been prepped with stains that dye bones and cartilage, an enzyme that digests flesh, and chemicals that render skin and muscles transparent. Because she was working with a three-dimensional subject, Marchiondo focused her camera on different planes of its body and then stitched 32 images together to create a single, crisp picture.



# ILLUSTRATION

EXPERTS' CHOICE & PEOPLE'S CHOICE

## NEUROFOREST

Matteo Farinella

Last spring, London neuroscientist-turned-cartoonist Matteo Farinella published *Neurocomic*, a graphic novel about a man who falls into a brain. In this illustration from the book, Farinella uses a forest metaphor to depict brain cells and neurons as a dense, sprawling network of intertwined tree roots and branches. "The brain is very

complex—there are billions of neurons connected in ways that we are only beginning to understand," Farinella says. Paul Lipton, a neuroscientist at Boston University, notes the image illustrates the brain's structural diversity. "The brain is indeed a forest," he says, "whose trees, or neurons, are its defining feature."

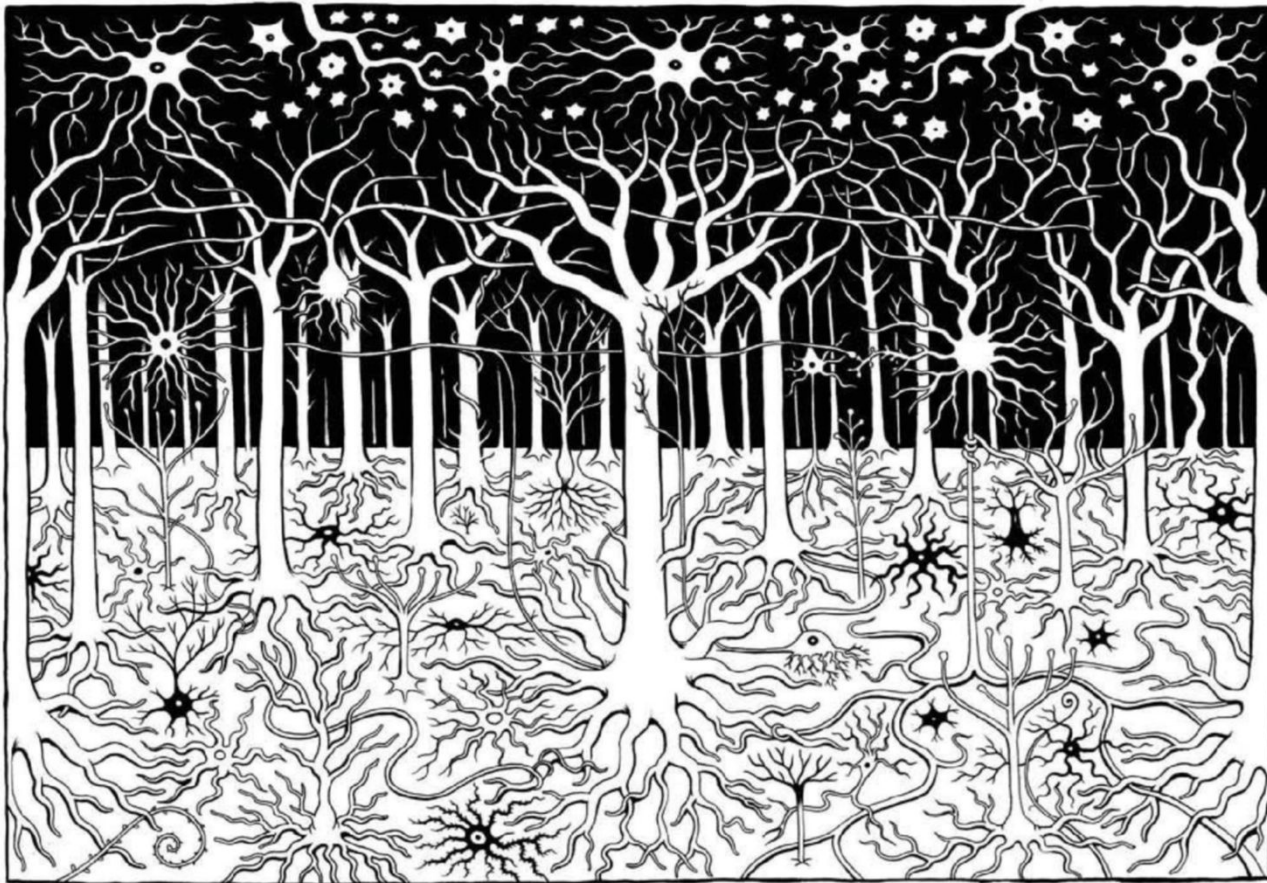


## HONORABLE MENTION

### JUAN FERNÁNDEZ FIRECROWN, CABBAGE TREE

Juan Luis Castillo

A pair of endangered hummingbirds—the cinnamon male and the emerald female—feed from an equally imperiled tree. Both species live only on an archipelago off Chile's coast.



## VIDEO

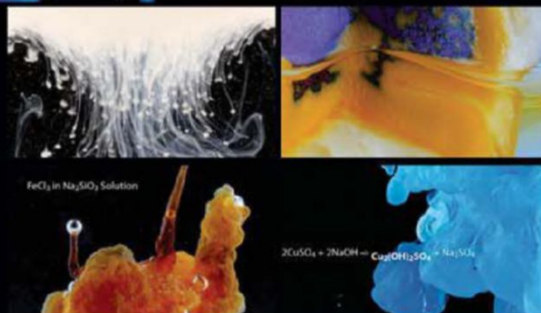
## EXPERTS' CHOICE

## BEAUTIFUL CHEMISTRY

**Yan Liang, Xiangang Tao, Wei Huang, Edison (Qi) Zheng, and Jiyuan Liu**

For many, the phrase “chemical reactions” conjures memories of tedious laboratory work and equations scribbled on exams. But Yan Liang, a professor at the University of Science and Technology of China in Hefei, sees art in the basic science. Last September, Liang

and colleagues launched *beautiful chemistry.net* to highlight aesthetically pleasing chemistry. Their video showcases crystallization, fluorescence, and other reactions or structures shot in glorious detail. Liang says finding experiments that meet their visual standards has been a challenge. “Many reactions are very interesting, but not beautiful,” he says. “But sometimes, when shot at close distance without the distraction of beakers or test tubes, ordinary reactions such as precipitation can be very beautiful.”



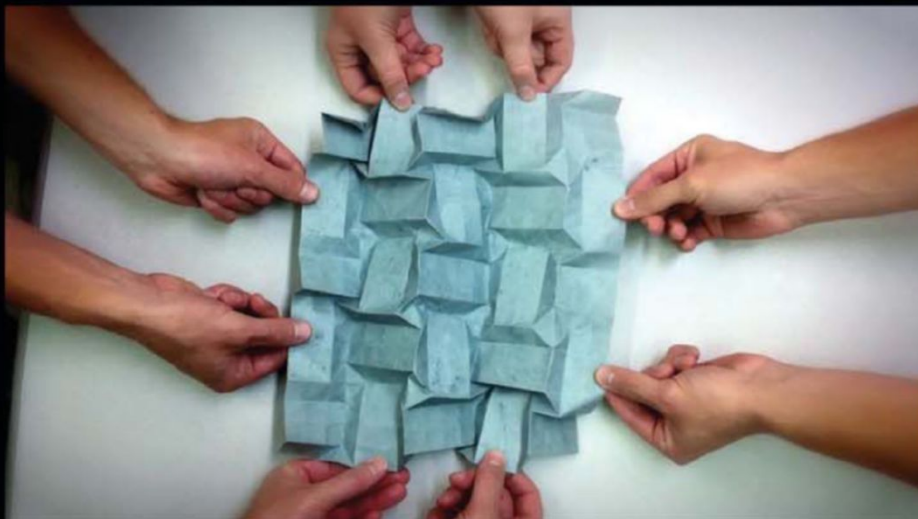
Precipitation, color-change, and other reactions were chosen for their eye-appeal.

## PEOPLE'S CHOICE

## HOW ORIGAMI IS INSPIRING SCIENTIFIC CREATIVITY

**Larry Howell, Julie Walker, Robert Lang, Spencer Magleby, and Brian Wilcox**

Engineers use origami to design spacecraft solar panels and other devices that collapse, flex, or unfurl. This video, by a lab at Brigham Young University, takes viewers on a tour of origami applications, big and small. Larry Howell, the team leader, says the work is just plain fun. Plus, he says, “these things can really make a difference.”





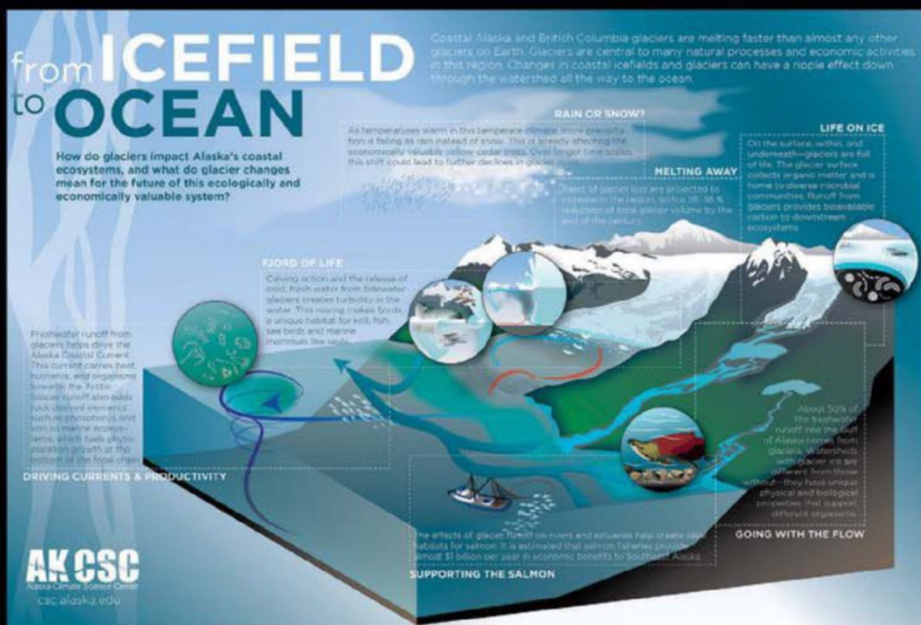
# POSTERS & GRAPHICS

## EXPERTS' CHOICE

### HIPPOCAMPAL NEURONS

Robert E. Clark

One of the most prominent structures in the brain, the hippocampus plays an important role in acquiring semantic memory, or general knowledge such as bird names, and in holding onto autobiographical, or episodic, memories. It also looks a lot like a sea horse. (Hippocampus is from the Greek for "horse" and "sea monster.") Robert Clark, a neuroscientist at the University of California, San Diego, played up the resemblance in this graphic. Clark digitally added images of real hippocampal neurons to a pair of gold sea horses. The sea horses are oriented as they would be in a rat's brain.



## PEOPLE'S CHOICE

### FROM ICEFIELD TO OCEAN

Kristin Timm, Shad O'Neel, Allison Bidlack, and Eran Hood

Alaska's coastal glaciers are among the most rapidly changing on the planet. They're also, as Alaska Climate Science Center communications lead Kristin Timm says, "more than just ice." Glacial runoff drives ocean currents and supports the habitats of the salmon that local fishermen rely on. So Timm collaborated with glaciologists and ecologists at the center to design this poster, which illustrates the impact of ice fields on both people and the environment.

# GAMES & APPS

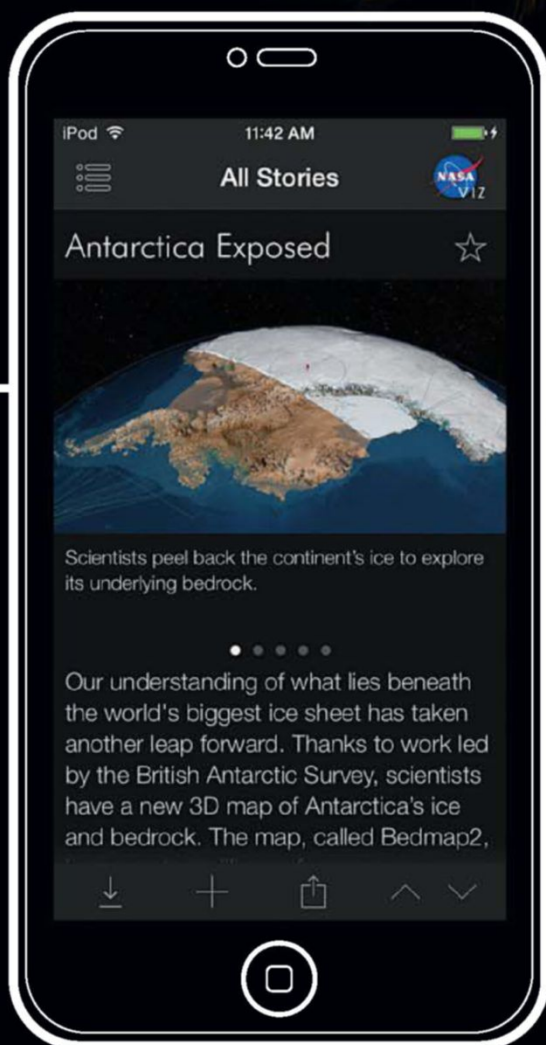


ILLUSTRATION PHOTO BY CREDIT HERE



## PEOPLE'S CHOICE

### NASA VISUALIZATION EXPLORER

**Goddard Space Flight Center's NASA Viz Group; Helen-Nicole Kostis, project manager**

Scientists at NASA collect reams of data about Earth and its place in the universe—data that often doesn't find its way to the public. So a team of media experts and programmers at the Goddard Space Flight Center in Maryland released this app, which publishes videos, images, and animations from several NASA agencies twice a week, along with a story sharing the science behind the visuals.

## EXPERTS' CHOICE

### GLASSBRAIN

**Adam Gazzaley, Roger Anguera-Singla, Rajat Jain, Tim Mullen, Christian Kothe, John Fesenko, Oleg Konings, Matt Omernick, and David Ziegler**

Part education tool, part neuroscience party trick, the Glassbrain app was first used publicly in 2012 on Mickey Hart, former drummer for the Grateful Dead, to show his brain reacting to music. A cap detects the different types of waves and signals pinging across a subject's brain. The app then displays them in real time on a 3-D image built from brain scans taken earlier. Right now, the app's not sophisticated enough for clinical applications—it's mainly used for education and entertainment. But Roger Anguera-Singla, one of Glassbrain's programmers at the University of California, San Francisco, says he hopes it will one day help medical professionals, too—for example, by allowing neurosurgeons to "fly inside" a functional brain and better plan an upcoming surgery.





# **NOWHERE TO HIDE**

*by* **P.W. SINGER**

**HARDWARE GOVERNS**

**OUR HOMES, CITIES,**

**INFRASTRUCTURE,**

**AND MILITARY.**

**WHAT HAPPENS**

**WHEN IT'S TURNED**

**AGAINST US?**

*photographs by* **SAM KAPLAN**



# In

late summer of 2006, the Japanese division of McDonald's decided to run a new promotion. When customers ordered a Coca-Cola soft drink, they would receive a cup with a code. If they entered that code on a designated website and were among 10,000 lucky winners, they would receive an MP3 player pre-loaded with 10 songs.

Cleverly constructed, the promotion seemed destined for success. Who doesn't like a Coke and a free MP3 player? But there was one problem the marketers at McDonald's could not anticipate: In addition to 10 free songs, the music players contained QQPass malware. The moment winners plugged their players into a computer, the Trojan horse slipped undetected into their system and began logging keystrokes, collecting passwords, and gathering personal data for later transmission.

McDonald's eventually recalled the devices and issued an apology, but not before an unknown number of users had fallen prey to the malware. In the annals of fast food promotions, the incident is still regarded as one of the worst of all time (even beating the ill-conceived McAfrika burger—an African-inspired sandwich released at the height of a famine). For security professionals, it was notable too, but for entirely different reasons: It offered a terrifying glimpse at how hackers could build a cyberattack directly into the very systems we depend on.

In the past year, cybercrime has blossomed into a pandemic, consuming more than \$445 billion in lost time, jobs, and intellectual property. Hackers compromised 233 million personal records from eBay; they intimidated Sony into scuttling the theatrical release of *The Interview*; they even commandeered the Pentagon's Twitter account. But as varied as those assaults were, they shared a trait: Someone

hacked software to penetrate a network or account. What set the McDonald's incident apart—and what strikes fear into cybersecurity professionals everywhere—is that the perpetrator hacked hardware instead.

In computing terminology, hardware boils down to microchips, the integrated circuits that run our devices. They are in our phones, refrigerators, electric grids, planes, and missiles. And many more are on the way. Cisco estimates that more than 50 billion Internet-connected devices will come online by 2020, all communicating ceaselessly with the world around them.

Microchips are the bedrock upon which our digital world is based, and they are almost entirely unsecured. Whereas software security is on pace to become a \$156 billion industry in the next five years, hardware security gets relatively little mention. Yet the challenges hardware presents are in many ways more extensive, more dangerous, and more difficult to combat. When the marketers at McDonald's ordered their MP3 players, they simply chose a device from a catalog. It just happened that someone at a production line in Hong Kong decided to load it with malware. We'll likely never know why that person chose those particular MP3 players, and that's not really the point. This kind of attack could have hit anywhere hardware exists, from coffeemakers to fighter jets, and the consequences could have been much, much worse.

## Problem from Hell

When Jack Kilby of Texas Instruments invented the first integrated circuit in 1958 (for which he later won a Nobel Prize), the age of the microchip was born. These early processors cost \$450 and consisted

of a few transistors, diodes, resistors, and capacitors placed onto a slice of germanium and linked by gold wires. The unit was about 10 millimeters across.

Today's microchips follow the same principles but are exponentially more complex. They consist of billions of transistors and are divided into multiple sub-units (called "blocks," as Kilby first labeled them), each of which carries out a specific function. A smartphone's processor, for example, may have some blocks whose purpose is to store frames of video and others to convert them so they can be sent over an antenna.

As the nature and complexity of chips has changed in five and a half decades, so too has their design and manufacture. In the 1970s and '80s, there were just a handful of known and trusted chip designers; **now there are a huge number of companies** creating more than 5,000 new designs each year, spread from the U.S. to Asia. These teams, in turn, involve hundreds or thousands of people at multiple locations—each working on different blocks. Chips have become so intricate that no one person can see, let alone understand, every detail of their architecture.

These developments have, by and large, been positive. The more powerful our microchips, the more capabilities we have. But when such complexity is paired with massive scale—\$333 billion-worth of chips were sold in 2014 alone—it also creates significant vulnerabilities, and an ever-more irresistible opportunity for hardware hackers. In a recent report for the Brookings Institution, John Villasenor, a professor of electrical engineering and public policy at University of California at Los Angeles, wrote, "The laws of statistics guarantee that there are people with the skills, access, and motivation to intentionally compromise a chip design." In other words, more

frequent and large-scale hardware attacks are just a matter of time. And when they come, whether from a nation state, a crime syndicate, or a rogue employee, they will arrive in one of two forms: overt or covert.

Overt actions are perhaps the simpler of the two: They make it apparent that the system isn't working properly. The best example would be a so-called kill switch, in which an enemy or criminal could selectively turn off chips at will. Doing this is easier than one might think. For example, the different blocks in a chip can communicate and coordinate via a "system bus," which they take turns using so as not to create interference. If one block was corrupted so it would not give up access to the system

hardware was modified ever so slightly, a kill code could selectively disable the chip and the systems that depend on it. And that code could come from any number of sources. A command could originate in a text or email message. It could be delivered by radio signal to a micro-antenna hidden on the chip. It could even be a simple internal time bomb, programmed at the chip's inception, to trigger a coordinated shutdown on a certain time and date, as in the first episode of *Battlestar Galactica*.

If an overt action is the equivalent of dropping a bomb, a covert one is like laying a landmine. A compromised chip may appear to function normally while secretly collecting and transmitting information,

greater harm were they to work their way into the backbone of the Internet: the servers and other networking equipment that comprise the infrastructure of the IT world. Instead of gathering embarrassing emails from a handful of executives, hackers with compromised servers could monitor most of the world's Internet messages. As companies such as Huawei Technologies and ZTE Corporation—both of which supply telecommunication equipment and have ties to the Chinese military—continue to grow, so too will concerns about network security. Add to that, the revelations by Edward Snowden indicate the National Security Agency (NSA) has moved from hacking individual computers to network hardware.

## **MICROCHIPS ARE THE BEDROCK** upon which our **DIGITAL WORLD** is based, and they are **ALMOST ENTIRELY UNSECURED.**

bus—something well within reach of many mid-level chip designers—it would prevent the other blocks from getting data, effectively disabling, or bricking, the system.

Just one small corruption can have grave consequences. In 2011, faulty transistors were found in an electromagnetic interference filter destined for a U.S. Navy helicopter (an SH-60 deployed to a destroyer in the Pacific Fleet). Though never installed, that defective part would have compromised the SH-60's ability to fire its Hellfire missiles, making it practically useless in combat. The manufacturer of the filter, Raytheon, and the U.S. Senate Committee on Armed Services had to trace the transistors through five companies before finding their origin in China.

An investigation later proved the flaws were an honest production error. But had someone intentionally pursued this sort of hack, the result could have been different. More than three-quarters of the field-programmable gate arrays in the F-35 strike fighter are made in China and Taiwan. So are the majority of chips in automobiles and wireless medical devices, such as pacemakers and dialysis machines. If that

launching malware from inside the system, or even coordinating with other corrupted chips to carry out a larger attack. In 2007, for example, the Taiwanese Ministry of Justice discovered that a number of Seagate hard drives had two separate Trojans built into them by someone in the design or manufacturing process. The malware would phone home to a pair of websites hosted out of Beijing, which would then cause the hard drive to upload all its data. More recently, the Star N9500, a knockoff of the Galaxy S4 smartphone, shipped from a factory in China preloaded with a Trojan masquerading as the Google Play Store. It allowed the attackers to record phone calls, read emails, intercept financial information, and remotely watch and listen in via the phone's camera and microphone.

Even hardware generally considered innocuous could be exploited by hackers and used for covert acts. Modified third-party phone chargers have served as vehicles for malware, as have game consoles. In the world of hardware hacking, any smart device—a refrigerator, clock, even a wearable fitness monitor—could be weaponized.

Such covert actions could inflict even

Perhaps the most devastating form of covert attack would be one that turns kinetic. Imagine a single employee at a microchip foundry hellbent on engineering an international crisis. Knowing the foundry's chips go into drone systems, that employee could embed a malfunction into the hardware that would activate only at a certain GPS point. When the drone reaches the designated position, say in northwest Pakistan, it would fire a missile at a school or dam instead of a militant camp.

The example is a worst-case scenario but hardly inconceivable. At a cybersecurity panel at the Aspen Institute in 2011, General Michael Hayden, a retired Air Force four-star general who headed both the CIA and NSA, was asked about hardware hacking, and his response was simple: "It's the problem from hell."

### **Lines of Defense**

**A**t this point, hardware hacking is still in its infancy, and so too are solutions to it. Chip designers primarily rely on protocols that have not appreciably changed for years. For that





reason, Villasenor wrote in 2010, “Defensive strategies have not yet been fully developed, much less put into practice.”

And so protection for consumers at this point comes down to common sense: If you don’t know where something is from, it’s generally not a great idea to plug it into your network. The advice sounds obvious, but it bears stating that the worst hack in U.S. military history occurred when someone found a corrupted memory stick outside a base in the Middle East and plugged it into a classified network.

Beyond simple schoolyard rules, creat-

design process. More robust encryption programs could track design changes, making it harder for someone to initiate a hack in the first place.

Testing, too, requires an overhaul. Tests today are “usually designed to weed out accidental defects and design flaws, not identify parts that counterfeiters have specifically altered to masquerade as something they are not,” Villasenor wrote in an article with co-author Mohammad Tehranipoor. And only a small percentage of the millions of chips produced each year are tested anyway. To fortify this vulnera-

memory gatekeepers that prohibit access to off-limits areas. Another would be to incorporate a “no execute” bit, which cordons off certain areas of memory and prevents the processor from executing any code from there. The appetite for such solutions, however, is still very limited.

### Chronic Condition

A few years ago, Cody Brocious, a 24-year-old researcher at Mozilla, began to investigate the security of the electronic room-lock systems used at many hotels, most of which can be programmed to accept master keys. At the 2012 Black Hat security conference, he showed off how to spoof a master key with little more than \$50-worth of homebrewed hardware. The lock manufacturer developed a defense against this attack, but it involves replacing the hardware in more than four million locks.

In the end, that’s truly what makes hardware hacking the “problem from hell”: The potential avenues of attack are so numerous and insidious, they can be hard to contemplate. Addressing them will be neither easy nor fast—but it can be done. The challenge of software security appeared equally insurmountable at one time, but now cybersecurity professionals are doing a better job of understanding and confronting those risks than ever before. As with software, the decision to pursue hardware security will ultimately come down to cost-benefit analysis. Added defenses often come with tradeoffs, namely lower performance, increased cost, or both. Until now, the decision to adopt them has been pretty easy—don’t bother. Going forward, the thought process will change. As James Hayward, the CEO of Applied DNA Sciences, said in an interview, “A \$100 microchip might keep a \$100 million dollar helicopter on the ground.”

That new calculus will hopefully spur governments and companies to attack hardware vulnerabilities before criminals do. “Frankly, it’s not a problem that can be solved,” General Hayden said of hardware hacking in Aspen. “This is a condition that you have to manage.” 

## ***“In the world of HARDWARE HACKING, any smart device—A REFRIGERATOR, CLOCK, even a WEARABLE FITNESS MONITOR—COULD BE WEAPONIZED.”***

ing defenses becomes much more difficult. To stop hardware hacking at the design and manufacture stage, the Pentagon has launched its “Trusted Foundry” program. To qualify, foundries that build integrated circuits must pass a rigorous accreditation process. It’s a good first step, but it affects only a small fraction of the chips the U.S. military needs, let alone the rest of us. The next step would be to expand the network of trusted chipmakers and punish companies found to be untrustworthy. But given the layers of buyers and sellers involved, that will be difficult. The researchers that detected the hack in the Star N9500 smartphone spent more than a week trying to find the source of the malicious chip, to no avail.

As foundries strive to improve their security, some researchers are investigating the development of digital watermarks, such as holograms or bits of plant DNA, that could be authenticated at key points in the supply chain. Other researchers are looking upstream to secure the microchip

bility, DARPA created the Integrity and Reliability of Integrated Circuits program. Its projects include an advanced scanning optical microscope that will use an infrared laser to probe “microelectronic circuits at nanometer levels, revealing information about chip construction as well as the function of circuits at the transistor level.”

The agency also launched the Supply Chain Hardware Integrity for Electronics Defense program. It aims to develop a dielet, a 100-micron-by-100-micron component that could be attached to chips at less than a penny per unit. It would carry an encryption engine to help secure data and sensors to detect any tampering.

Each program holds a lot of promise, but to truly safeguard hardware vulnerabilities chip designers need to rethink chips themselves. That means building defenses directly into integrated circuits. One example could be to install input and output monitors that stop chips from communicating with unauthorized connections and





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# Manual

EDITED BY *Sophie Bushwick*

## STATS

**Time** 1 hour

**Cost** \$40

**Difficulty**



## ORIGIN STORY

After discovering the momentum curtain effect, Sir Christopher Cockerell launched the first full-scale hovercraft in 1959.



## A HOVERCRAFT BUILT FROM STYROFOAM PLATES

**WARNING:** The fans don't generate much power, but they can still cause minor cuts and bruises. Keep your fingers clear!



If you believe the old Hollywood prophecies, Marty McFly will be hopping out of Doc Brown's DeLorean this coming October (on the 21st, to be exact). And when he gets to the future, he'll need a hoverboard. You can do your part to prevent a time paradox—just slap together this low-budget hovercraft

from a pair of Styrofoam plates and four surplus case fans. The stacked plates force the breeze from the fans into a wall of downward-directed air around the edge of the craft. This wall, called the momentum curtain, raises the pressure of air trapped underneath the craft, increasing lift and allowing it to hover. The "hoverplate" won't carry your weight, but it will glide effortlessly over any smooth surface like a giant, self-powered air hockey puck. Great Scott!  
SEAN MICHAEL RAGAN

# 10,000

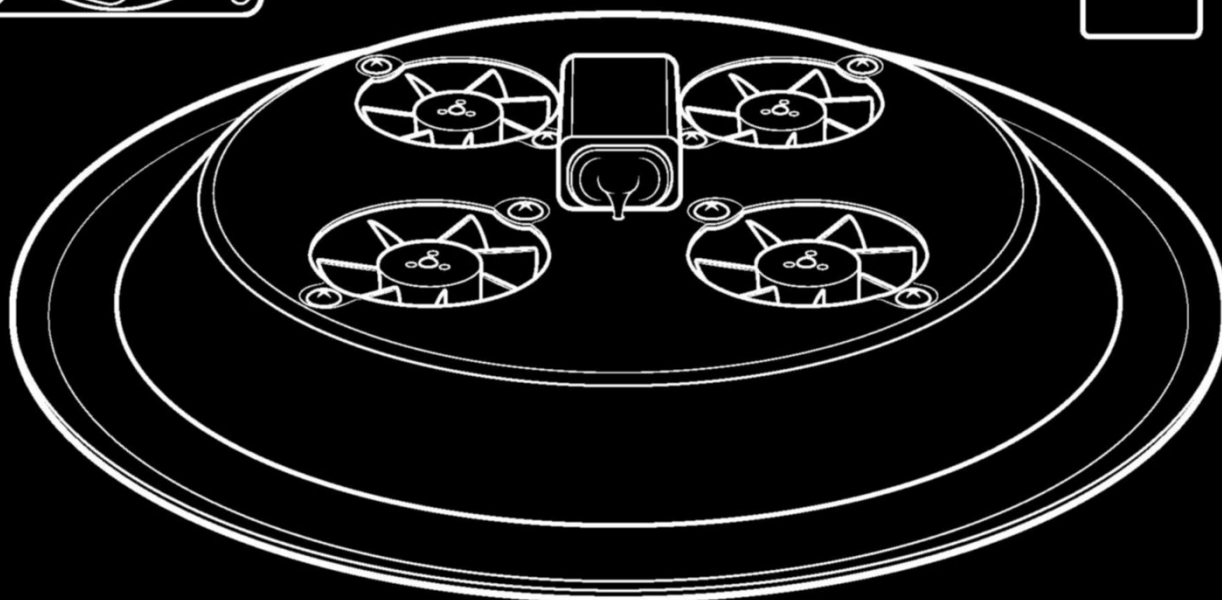
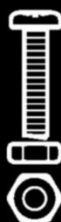
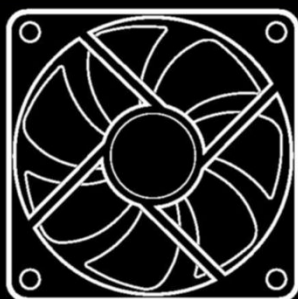
Price, in dollars, of a working Hendo hoverboard prototype

continued on page 66



# Build It

continued from page 65



## MATERIALS

- 2 11-inch-wide, 1-inch-deep foam plates
- 4 small (50 mm x 10 mm)

- 5-volt case fans
- 9-volt NiMH battery
- 9-volt battery clip

- 2 wire nuts, 22-18 AWG
- 8 5/8-inch 6-32 nylon screws and hex nuts

## TOOLS



Utility knife



Drill



Wire strippers



Hacksaw

## INSTRUCTIONS

**1** Stack the plates face-up and arrange the fans in a circle on top, with labels up. Point the wired corners toward the center, with the opposite corners close to the rim. Mark the top plate with the locations of each fan's opening and its inner- and outer-corner mounting holes.

**2** Remove the fans and drill eight 3/8-inch mounting holes through both plates. Separate the plates and cut out the four circular fan openings in one of them. This will be the top plate.

**3** Attach the battery to the battery clip, and set it in the center of the top plate. Note the location of the battery clip wires

and cut a small triangular slot for them to pass through.

**4** Saw two corners off each fan case, leaving the wired corner and the one opposite attached. Arrange the fans inside the top plate as in step 1, and pass nylon screws, from below, through the eight mounting holes in both the top plate and the fans.

**5** Trim the fan wires to reach about an inch past the center of the plate, and then strip half an inch of insulation from each.

**6** Thread the battery clip wires through the triangular slot from below and pull the battery and clip up close to the plate. Then trim the wires until they just reach the plate center.

Strip half an inch of insulation from each wire and unclip the battery.

**7** Twist all five red leads (four from the fans and one from the battery clip) together with one wire nut, and all five black leads together with the other.

**8** Cut the rim off the bottom plate, about halfway down the side, and discard

it. Install the bottom plate inside the top plate, so it fits over the fans and protruding screws, and secure it with eight hex nuts.

**9** Flip your hovercraft over, clip in a freshly charged battery, and set it on a smooth floor.

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# The Roman Catapult Revived



**Long before** the invention of gunpowder, ancient armies used siege engines to hurl all sorts of terrible, yet creative, missiles at each other. The Carthaginians put poisonous snakes in clay jars and launched them at enemy ships. The Romans threw bags of bees at their foes. And the Mongols enjoyed an early but gruesome form of germ warfare that involved tossing plague-infested corpses over the walls of castles.

While reading about the bad old days, it struck me that a replica Roman legion-style catapult might be just the thing to bring excitement to my next neighborhood block party. I found content written by original Roman and Greek catapult engineers in a textbook, then designed my model to be fairly authentic—although I did use modern tools and materials. And for convenience, I decided to scale down the size.

A spring made from twisted rope provides the power behind the catapult's arm. (The ancients used horsehair, among other materials, but I found that natural fibers like hemp and sisal, which stretch less than nylon rope, also make excellent catapult springs.) When fully wound, the rope places immense stress on the entire structure, so it's important to build the wooden frame solidly. Without the pair of cross-braces I added, the machine would implode when the spring was tightened.

The taut spring also makes it difficult to release the catapult's throwing arm quickly. But a little mechanical device called a panic snap, available at hardware stores, makes a fast, controllable trigger.



It disconnects easily because its latching mechanism is separate from the load-bearing structure.

But even with a good trigger, hurling the ammo properly can be tricky. Let go too early, and it shoots straight up. Too late, and it plows into the ground in front of you. I attached a cord to my projectile and looped the other end around a peg in the top of

the throwing arm. The cord, with its attached payload, slips off the peg at just the right time. And its length controls how far the missile will fly.

Instead of flinging bolts, Roman style, I tried baseballs, burritos, and even full cans of beer (the latter, it turns out, are not a great idea). My tactics may not have won any battles—but they sure were fun.

For instructions on building your own Roman catapult, check out [popsci.com/DIYcatapult](http://popsci.com/DIYcatapult). And send photos and video of your creation to [historystrikesback@popsci.com](mailto:historystrikesback@popsci.com).

IN **HISTORY STRIKES BACK**, COLUMNIST WILLIAM GURSTELLE GIVES ANCIENT WEAPONS A MODERN DIY SPIN.

**WARNING:** Keep body parts clear of the throwing arm and remember to wear eye protection. And when choosing projectiles, exercise common sense.



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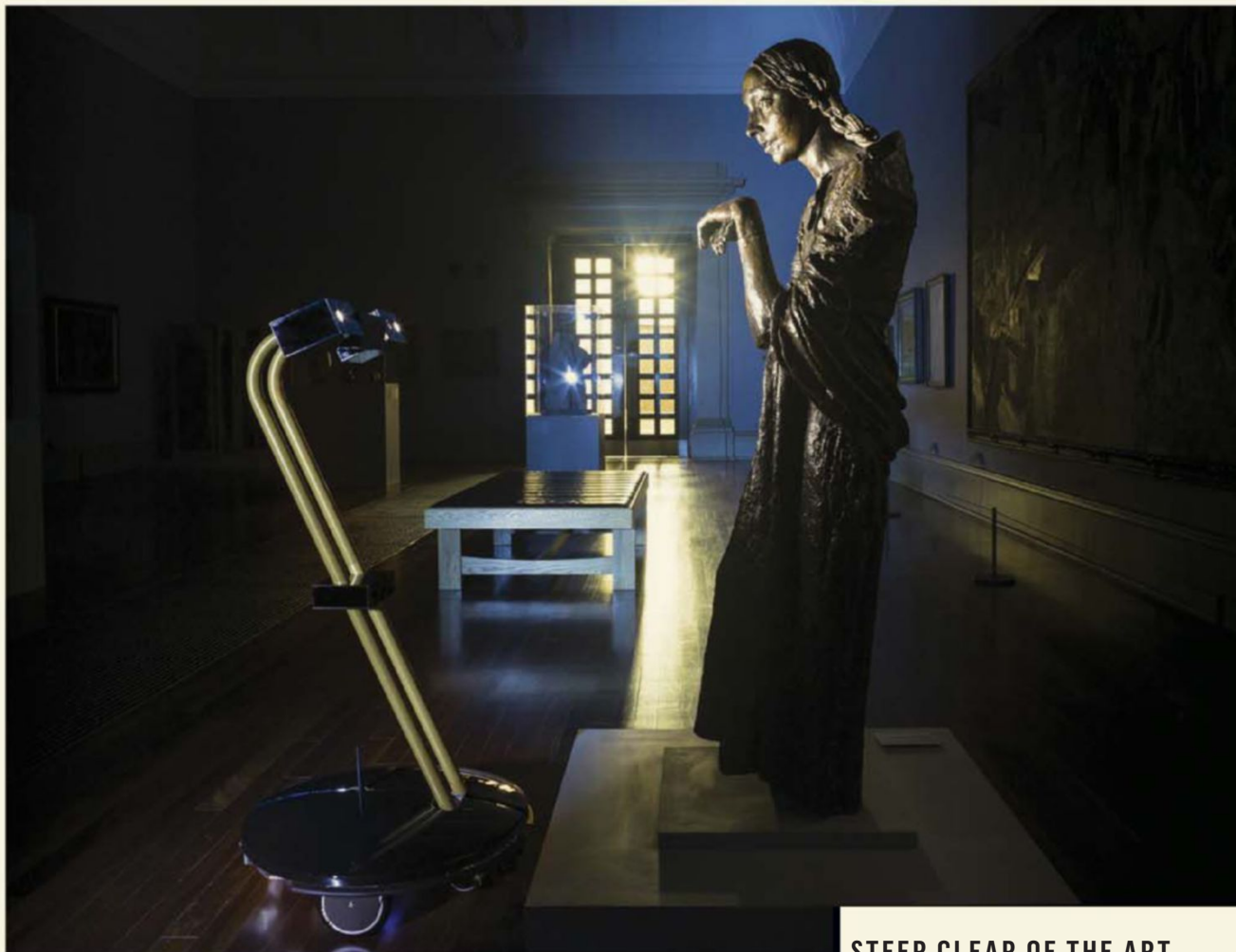
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100,000

Number of people who watched the live stream of "After Dark"

# Robot Night at the Museum



↓  
In the darkness of the deserted museum, something inhuman stirred. A pair of headlights swept around a corner, illuminating a statue—as a camera streamed the sight to viewers around the world. The nocturnal intruder was part of “After Dark,” an event series in which robots roam a public space when the crowds have gone home.

During the first “After Dark” event, in August 2014, about 500 people got a chance to explore London’s Tate Britain via one of four robots. Tate had selected “After Dark” and its creators, designers Ross Cairns and Tommaso Lanza, for its annual IK Prize, which awards technology projects that bring art to a larger audience. While one of the 500 volunteers used online controls to steer the robot, everyone else could watch a live feed

as art experts provided commentary.

Viewing art after hours is familiar to Cairns and Lanza, who have produced interactive exhibits in several museums and galleries. “Working in these amazing spaces, we often walked around the galleries at night by ourselves—public spaces where we were really not supposed to be,” says Cairns. “We wanted to re-create that experience.”

The robots’ next deployment is top secret—for now. Keep an eye on the project’s Twitter handle, @afterdarkrobots, or sign up for its mailing list. **ALLIE WILKINSON**

## STEER CLEAR OF THE ART

Cairns and Lanza built the bots from laser-cut and machined parts, along with DIY electronics. To avoid knocking over priceless works of art, the robots use sonar, which detects sound waves as they bounce off

obstacles. If an object blocks a robot’s path, it won’t proceed forward, even when its driver orders it to. The designers also built in a fail-safe: If one of the sensors stops working, a switch will cut off power to the bot.

**“IN THE DEAD OF NIGHT, WE WERE SNEAKING UP ON STRANGE ROBOTS OPERATED BY OUTSIDERS ON THE OTHER SIDE OF THE PLANET.”** —ROSS CAIRNS

“AFTER DARK” ROBOT WITH JACOB EPSTEIN’S THE VISITATION (1926). “AFTER DARK.” THE IK PRIZE ©2014. COURTESY TATE MODERN PHOTOGRAPHY: ALEXEY MOSKVIN ©2014

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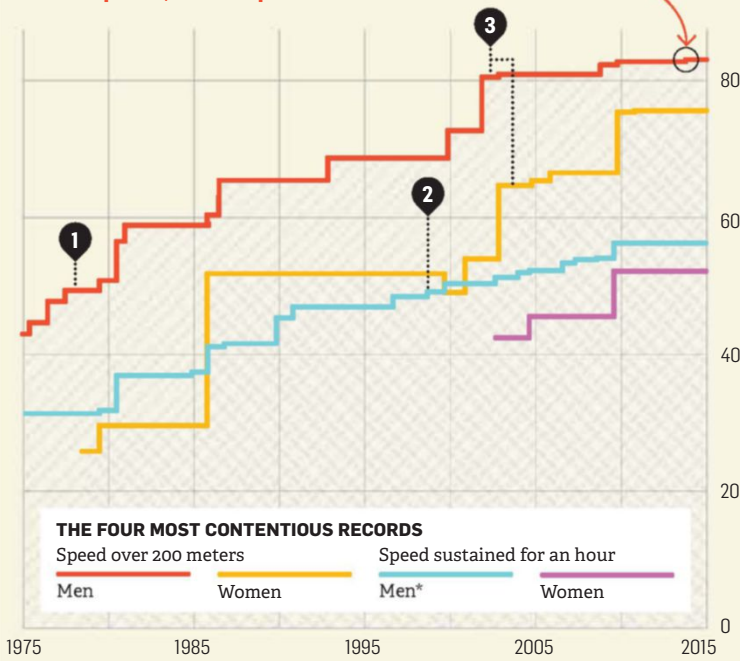
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World human-powered speed record, in miles per hour, set in 2013 by Sebastiaan Bowier of Human Power Team Delft in the VeloX 3 bike

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Record speeds, in miles per hour



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Speed over 200 meters: Men (red line), Women (yellow line)  
Speed sustained for an hour: Men\* (light blue line), Women (purple line)

- 1 The Beginning**  
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- 2 Big Money**  
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- 3 Battle Mountain**  
An annual competition begins on a straight, flat highway near Battle Mountain, Nevada. One-hour events need a longer track, but with five miles to build up speed, 200-meter records shoot up.

\*Some records appear slower because the IHPVA distinguishes between high- and low-altitude records. The first two men's one-hour records, from 1932 and 1938, are omitted for space.

SOURCE: INTERNATIONAL HUMAN-POWERED VEHICLE ASSOCIATION



✓Yes



✓Yes



xNo



✓Yes



✓Yes



✓Yes



✓Yes



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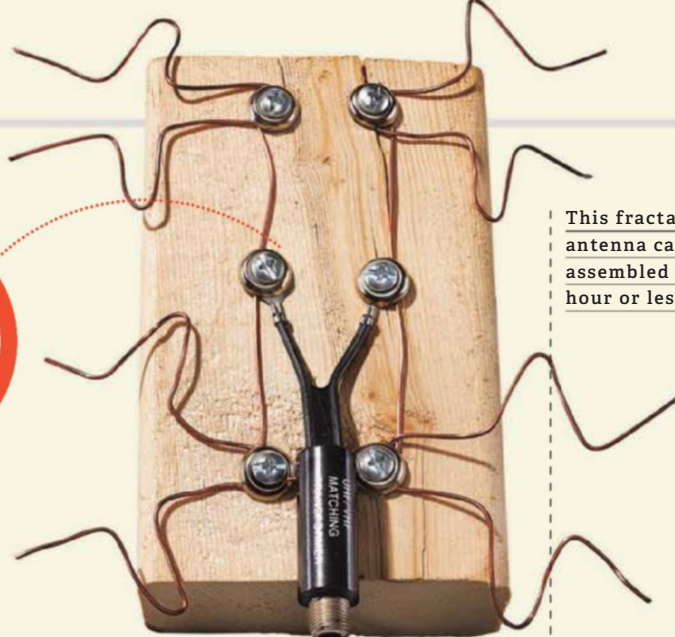
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# LEARN TO DEFY THE CABLE COMPANY



This fractal antenna can be assembled in an hour or less.



**Frustrated by years** of expensive cable bills, Norm Sutaria ditched his set-top box and used online instructions to build a homemade HDTV antenna. Then the education specialist shared his newfound expertise with a class at Brooklyn Brainery, a crowd-sourced education space in New York City. *Popular Science* sat in to learn how to nab affordable, high-resolution television. **ALEXANDRA OSSOLA**

## Design

Students in Sutaria's class built either a 32-inch "bow tie antenna," reminiscent of the classic rabbit ears, or an eight-inch "fractal antenna," pictured here, which is more compact and slightly harder to make.

## Assembly

Both designs were simple: a few pieces of copper wire arranged on a block of wood using nails and washers. The wires pick up HDTV signals and send them to the television via a matching transformer.

## Background

Sutaria explained that the electromagnetic waves that make up HDTV signals vary from 174 to 806 megahertz, falling within the spectrum of radio waves. In this span, each TV station has a unique range.

## Fine-Tuning

Wires must have the right length and position to pick up the waves. Trimming them and adjusting their positions by bending them forward or backward can optimize the antenna for your location.

PHOTOGRAPH BY JONATHAN KAMBOURIS

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*Eric Priess, Health & Science*

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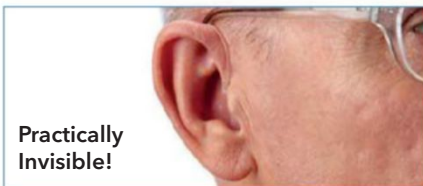
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Go Ahead...

# Ask Us Anything

ANSWERS BY **Daniel Engber** / ILLUSTRATIONS BY **Jason Schneider**

## What's the worst possible password?

**Short answer** *Password1* is pretty bad.

**A**

**Last fall**, hackers leaked 10 million email passwords on a Russian Bitcoin forum. Bogdan Calin, the chief technology officer for Web security firm Acunetix, sifted through the data and found almost 50,000 Gmail accounts with the same password: *123456*. In fact, strings of consecutive numbers comprised half of the top 10 most common codes.

While disturbing, stolen passwords may not be the best source of information on personal security habits. "When you're collecting hacked passwords, you're getting passwords that are hackable," says Mark Burnett, an independent security expert. "Often times the data come from places that don't have strong policies, or sites that no one really cares about protecting." That may be why data-dumps like this one include so many obvious duds. Burnett's own collection of 30 to 40 million leaked accounts contains *password* at least 150,000 times.

Other leaks suggest that more stringent security policies may not yield more sophistication. A 2009 hack revealed a long list of passwords with at least one number and one capital letter. *Password1* topped the list, with *P@ssw0rd* and *Passw0rd* not far behind.

To improve account security, Burnett says to use at least 10 characters and avoid common phrases. But even that may not offer much protection. "The capability of cracking passwords has gotten so

great. We have things to make them stronger, like two-factor authentication, but on their own, passwords are kind of at the end of their effectiveness." That means while the worst passwords are obvious, there's really not a best one either.



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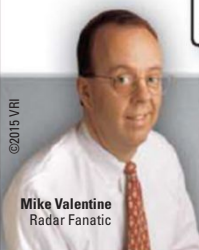
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## DO FISH GET OUT OF BREATH?

**Short answer** Do bears poop in the woods?

# A

**Fish need oxygen**, and, yes, sometimes they run short of it. There are roughly 30,000 different fish species and they respond to exertion in different ways, says Jeffrey Richards, a biochemist at the University of British Columbia who studies hypoxia and stress. Salmon, for example, work really hard when they traverse rapids or waterfalls, but it doesn't leave them gasping. The effort is more akin to weightlifting than running, says Richards. The fish's muscles will tire before they run out of oxygen.

That's a bit different for tropical fish. While salmon live in cool water, which typically has lots of dissolved oxygen, tropical fish are more likely to find themselves in oxygen-poor environments. As a result, they've developed several special adaptations to being short of breath. Some

species, including many of those sold for home aquariums, will engage in "aquatic surface respiration." They swim upward for swigs from the top-most layer of water, which has been exposed to the air and therefore contains more oxygen. Others—including sculpins and gunnells—pop out of the water for gulps of air. And then there are those, like the lung fish, who use internal organs as makeshift lungs, absorbing oxygen into the blood through the walls of their mouth, swim bladder, or even stomach.

**Note:** A fish will never get so short of breath that it passes out. It'll rest near the sea floor to save energy, or surface in search of oxygen first. Making themselves that vulnerable might seem risky. "But if they're the only animals still alive at such low levels of oxygen, they won't be picked off by predators," Richards says. It doesn't matter if you're exposed so long as you're the last fish swimming.

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# ARE APHRODISIACS FOR REAL?

**Short answer** You'd be better off with a little Marvin Gaye.



# A

If you're in the market for a natural aphrodisiac, you've got options. A research review from 2011 listed 34 plant species that have produced amorous effects in lab animals. "But the vast majority of products marketed as natural aphrodisiacs have not been scientifically proven according to Western standards," says Rany Shamloul, a doctor at the Ottawa Hospital Research Institute who has treated male sexual dysfunction.

Researchers have done preliminary (but inconclusive) studies on the aphrodisiacal properties of an assortment of plants and animals, among them the Malaysian sea slug known as "dugu-dugu," a chemical from the skin of the Bufo toad, priapic venom drawn from yellow scorpions and Brazilian "armed" spiders, the ambergris in sperm whales, and a

protein found in the vaginal secretions of hamsters. "Every culture has its own," says Shamloul. "In North America, there's a myth about oysters; I don't know why."

In 2014, Shamloul published a literature review for which he found a few positive results from animal studies, but no methodologically sound human studies. Despite his skepticism, Shamloul came across reasonable evidence in support of Korean red ginseng: "That one has been proven better than placebo."

Synthetic drugs, including those that affect the release of dopamine in the brain (which are often prescribed to patients with Parkinson's disease), can cause hypersexual behavior. "That side effect only affects 2 or 3 percent of users, but it's there," says Shamloul. "It means there are other drugs that can enhance the sexual drive." Perhaps more effectively than a bowl of tiger penis soup. 

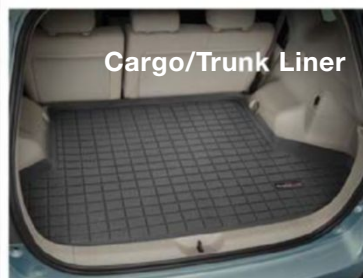


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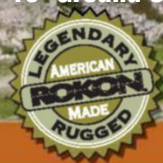
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## From the Archives

# All Aboard the Boat Train



In the 1600s, French engineers built the Canal Du Midi, which connected the Atlantic Ocean to the Mediterranean Sea. But sometimes a canal just isn't expeditious enough. In November 1932, *Popular Science* wrote about a wild plan to replace the canal with a 300-mile railway. According to the engineer who proposed it, the giant, 650-foot-long canal locks would act as train cars, driving down into the water to pick up ships, and after rolling across land on rails, drop them off on the other side. This would supposedly shave time off the trip and cost less than building a new water channel. Alas, we'll never know. The project never moved forward. But the issue of how to improve canals stays with us today. This year the Panama Canal's much-needed upgrade will be completed. To read more about the project, turn to page 30. **LINDSEY KRATOCHWILL**

# 1,100

Length, in miles, of China's Grand Canal, parts of which were constructed in 4th century BCE. It remains the world's longest manmade waterway.



## A BRIEF HISTORY OF CANALS

### 12th Century

About 85 percent of medieval transport in Europe is facilitated by inland waterways, bringing a boom of commercial canal expansion.

### 1373

Perhaps the first example of the modern pound lock is used in Vreeswijk, Netherlands, where the river's water level is higher than that of the canal.

### 1825

New York state opens the Erie Canal, which linked the Midwest's crop production with the Northeast's machinery manufacturing.

### 1869

After 10 years of construction, the Suez Canal is completed. The 105-mile lockless waterway is frequently improved during the decades to come.

### 1914

The Panama Canal is finished after a construction period marred by yellow fever. The canal has 23 changes of direction and is 51.2 miles long.

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